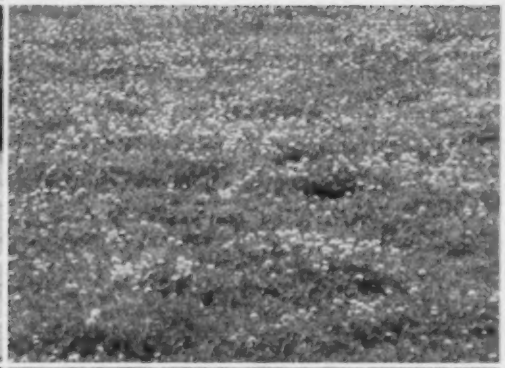
PASTURE PRODUCTION

Publication 19



Ministry of Agriculture,
Food and Rural Affairs

Ontario

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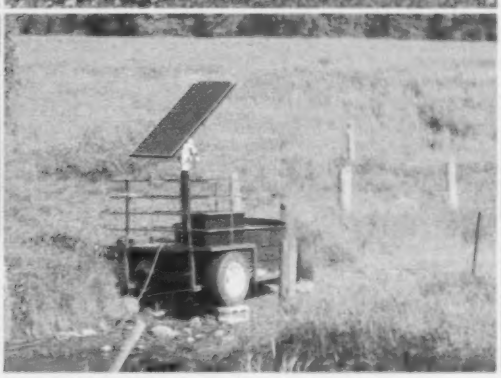

Ministry of Agriculture,
Food and Rural Affairs

Ontario

Pasture Production

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1. Pastures

INTRODUCTION

When Cato, the Roman philosopher, was asked more than 2,000 years ago what was the most profitable thing a farmer could have, he replied, "A first-class pasture." Somewhat startled, his questioners then asked what the second most-prized possession would be. "A second-class pasture," was his ready reply.

In Ontario, livestock producers use over a quarter of a million hectares of improved pasture and almost half a million hectares of unimproved pasture land. The combined area provides the cheapest source of nutrition for beef and dairy cattle, sheep, goats, horses, deer, elk, bison and other exotic ungulates that help to diversify Ontario's agriculture. Besides providing nutritious low-cost feed, they allow farming to be carried out in parts of Ontario where other crops cannot be produced and allow farming without soil depletion. The perennial forage species that make up a pasture provide continuous ground cover that reduces soil erosion, improves water infiltration, reduces water runoff and provides habitat for many plant and animal species.

First-class, and even second-class, pastures don't just happen. They are the result of good management — management based on the knowledge of how plants grow, their fertility requirements and their ability to withstand grazing and trampling by animals.

Pastures can be improved through a combination of weed and brush control, fertilizing, reseeding to higher-producing species and grazing management. This publication highlights the principles and management practices for top production and utilization of pastures in Ontario.

TYPES OF PASTURES

Natural Unimproved Pastures

The climax vegetation for most of Ontario is mixed conifers and deciduous forest. The exception to this is a pocket of prairie land in the southwest. What this means is that for most of the province, only shade-enduring grasses and those adapted to wet locations were found by the early European settlers. They were dissatisfied with the production from the native grasses and more comfortable using plant species from their homelands. The end result is that most of the so-called natural grasses that now inhabit pastures, roadsides and roughland in Ontario are the survivors of the grasses introduced by settlers. (O. McConkey, *Pasture Survey*, 1931.)

Kentucky bluegrass, Canada bluegrass and redtop are the three dominant grass species found in unimproved areas.

Kentucky bluegrass grows on the better, well-drained clay loam soils, while Canada bluegrass is dominant on heavy clay soils, sandy soils and shallow soils. Redtop is the dominant grass found on poorly drained acid soils or areas with very low fertility. While these grasses may dominate in specific areas, they are not the only plant species present (see *Occurrence and Abundance of Major Characteristic Species in Roughland Pastures*).

Occurrence and Abundance of Major Characteristic Species in Roughland Pastures

In *Roughland Pasture Assessment and Improvement Project*, E.M. Watkin and J.E. Winch list the occurrence of major species in roughland pastures:

Deep soil pastures: >30 cm deep	
Canada bluegrass	10 plants/m^2
Black medic	0–1 plants/m^2
Golden rod	0–1 plants/m^2
Silvery cinquefoil	0–1 plants/m^2
Shallow soil pastures: <30 cm deep	
Canada bluegrass	10 plants/m^2
Wild strawberry	1–10 plants/m^2
Oxeye daisy	0–1 plants/m^2
Hawkweed	0–1 plants/m^2

Annual Forage	April	May	June	July	August	September	October	November	Avg. Yield t DM/ha
Oats*									2.5–4.5
Fall rye									1.0–1.5
Winter triticale									1.0–1.25
Annual ryegrass**									8.0–12.0
Sorghum-sudan									8.0–12.0
Forage rape									7.0–9.0
Kale									9.0–12.0
Stubble turnips***									6.0–9.0

* Oats can be seeded throughout the season to provide grazing 6 weeks later.
** Production depends on adequate moisture conditions.
*** Requires adequate moisture.

Figure 1–1. Availability of annual forages during the pasture season.

Natural pastures are complex plant associations whose composition is influenced by the growing conditions, the weather and the animals using the area.

Natural pastures provide good grazing in the spring, but by mid-to-late June, production slows to a standstill. On average, unimproved roughland pastures produce 80% of their total production by the end of June. Consequently, these pastures have a low seasonal carrying capacity.

Species found in natural pastures are rarely highly productive.

The persistency of sown pastures is dependent on:

- selecting the right seed mixture
- establishing a good stand
- proper fertilization
- grazing management

Improved Pastures

Improved pastures have been reseeded, fertilized or fenced to improve productivity and utilization. This term is usually applied to rundown fields that have been renovated or rejuvenated.

Annual Pastures

Annual crops can be part of a planned pasture program or an emergency remedy in years when the regular pastures have been winterkilled or are suffering from drought. Figure 1–1. *Availability of Annual Forages During the Pasture Season*, shows the role that annuals can play in filling the pasture season. While annual crops offer flexibility in pasture programs, the advantages must be weighed against the cost of reseeding each year. For supplementing pastures in the summertime, consider grazing hay aftermath (second growth) or feeding hay.

ANNUAL PLANT SPECIES FOR PASTURES

Spring Cereals

Cereals are annual grasses and are a good choice when extra pasture is needed quickly. Any of the cereals, when grazed early enough in the vegetative state, will show some regrowth. In the vegetative state, cereals are a good source of protein but have very low dry matter and fibre content. Consequently, animals cannot obtain enough energy or fibre from grazing young cereals alone and should be provided with additional dry hay. To avoid having to supplement with hay, delay grazing until the cereals have started to head out.

A main goal of pasture management is to keep the pasture productive by preventing the succession to less productive species.

Since cereals tend to be nitrate accumulators, if large amounts of nitrogen fertilizer are applied during cool growing conditions or cloudy periods, the plants may accumulate toxic levels of nitrates. To prevent this, limit nitrogen applications to 30–50 kg of nitrogen/ha. Cereals produce the maximum amount of forage when seeded and fertilized for good grain yields. See OMAFRA Publication 811, *Agronomy Guide for Field Crops*, available at ontario.ca/crops, for details on fertilizer rates.

Cereals differ in productivity, palatability and feed value. Considering everything, oats are the most palatable and are the preferred spring cereal for grazing.

Oats

Oats are ready to be pastured 6–8 weeks after being seeded and can be seeded anytime from spring to fall. Early spring seedings can be cut for hay and the aftermath grazed until fall. Seed at 80–100 kg/ha.

Oats grown as a companion to an establishing forage crop can also provide an additional source of early summer pasture. Seed the oats at a low rate, 30–40 kg/ha, and graze when 20 cm tall. This not only provides good pasture but also helps the establishing forage crop by eliminating competition from the oat crop. This allows the young forage plants to grow more vigorously and consequently establish a thicker, higher-yielding stand.

Winter Cereals

Fall Rye

Fall rye is a versatile pasture crop. It can be grazed in the fall and, if seeded before mid-August, the following spring as well. The fall growth can be grazed until snow cover is too deep for the animals to dig through. If seeded on land that dries quickly, fall rye can provide very early spring pasture, but the land must be firm enough to carry the livestock.

Fertilize rye that is to be grazed in the spring with 50–80 kg of nitrogen/ha just when the plants start to turn green. Rye that is grazed early and has the animals taken off before it starts to mature can still produce a grain crop if growing conditions are good. This crop matures extremely rapidly after mid-May. Pay careful attention to the stage the crop is in, grazing before heads emerge. Seed at 150 kg/ha and fertilize to soil test recommendations.

Do not allow animals to graze young forage plants. Remove animals from the field as soon as they have grazed off the oats.

Winter Triticale

Winter triticale is a cross between wheat and rye that provides early spring grazing. It can be grown on a variety of soil types but, like fall rye, should not be sown on poorly drained soils. Seed early enough in the fall to provide time for the crop to establish itself. The date of seeding differs with location. See OMAFRA Publication 811, *Agronomy Guide for Field Crops*, available at ontario.ca/crops, and use the seeding dates suggested for winter wheat. Seed winter triticale at a rate of 100–125 kg/ha. In the spring, as the triticale is starting to turn green, fertilize with 80 kg nitrogen/ha.

Annual Ryegrass

Annual ryegrasses produce top-quality forage. There are two types of annual ryegrass available — Italian and Westerwold. The Italian type is really a biennial and may or may not survive our Ontario winters, so is regarded as an annual. Italian ryegrasses are leafy, short-growing (up to 40 cm) and, in the seeding year, do not come into head. These factors make Italian ryegrass an ideal pasture crop.

Westerwold annual ryegrasses grow taller (40–80 cm), have more stems and will head out if left to mature. Graze or cut Westerwold ryegrasses before they head out to maintain high productivity and feed quality.

For maximum yields and quality, annual ryegrasses require top management. Yields range from 8–12 tonnes of dry matter/ha when there is adequate rainfall, but its need for a constant water supply limits its use in Ontario. The shallow root system makes it ill-equipped to access water reserves when rainfall is scarce, and during periods of little or no rain, the plants stop growing and may die.

Seed annual ryegrass in early spring at a rate of 20–25 kg of seed/ha, using a cultipacker-type seeder. Roll the seedbed well to ensure good seedling emergence. Since highly fertile soil is needed to support the rapid, high production of forage, use a soil test to determine the phosphorus and potassium requirements, and apply high rates of nitrogen in split (at least three) applications. Ryegrass will be ready 6 weeks after seeding and, if enough moisture is available, will remain productive until late fall.

Sorghum-Sudan Grass Hybrids

Sorghum-sudan grass hybrids can be used for pasture as well as for stored feed. When pastured, start grazing after the plants have reached a minimum height of 75 cm. This will maintain productivity and eliminate the danger of prussic acid poisoning. All members of the sorghum family contain dhurrin, a glucocide that breaks down to release prussic acid, a compound that can lead to poisoning (also called hydrocyanic acid). Normally, the amount is not enough to cause problems, however, young plants, plants suffering from drought or plants that have been frosted contain a much higher level of prussic acid. Do not graze when it is recovering from drought stress, and wait until the frosted plants have dried out completely.

Once they have reached a height of 90 cm, sorghum-sudan grasses grow very rapidly. Good management is necessary to keep ahead of the growth. Successive plantings, strip grazing or mechanical harvesting may be required to avoid oversupplies of overly mature forage. Strip grazing is the best approach to pasture management, as it reduces trampling losses.

Plant sorghum-sudan grasses during the last part of May or early June at 14–20 kg/ha. Use the lower rate when seeding in 18-cm or 36-cm drill rows. The higher rate is for broadcast plantings. Fertility requirements are similar to corn.

Never allow horses to graze sorghum-sudan grass hybrids. Horses may develop cystitis, a potentially fatal urinary tract infection. Cystitis looks like colic, with blood in the urine.

Forage Brassicas

Forage brassicas can provide good pastures from September to December. Forage rape, kale and stubble turnips are the three brassicas most commonly used for pasture. They produce up to 12 t/ha of high-quality dry matter for fall grazing. Forage rape and kale are preferred by cattle and sheep.

Seed the brassicas in well-drained fields with a pH of at least 6 and adequate fertility according to soil test recommendations. Crops planted on poorly drained soils do not do well and grazing losses are high. All three species are small-seeded and produce maximum yields when precision drilled into rows no more than 1.5 cm deep. However, good stands can also be established by broadcast seeding.

All three brassicas should be planted in the summer, and seeding dates are important for all of these as delays past the recommended dates cause large declines in yields. They will germinate and then not grow very much during hot dry weather. Once day and night temperatures cool and more rain falls, they grow quickly.

Strip graze brassicas to avoid excessive wastage. Brassicas have a high moisture content, 85%–89%. To ensure enough fibre in their diet, either feed your animals hay or give them access to permanent grass/legume pastures.

If not well managed, all the brassicas can cause animal health problems.
See Chapter 7, *Animal Health Problems*.

Kale

Kale, also called marrow stem kale, has a short (75 cm–1.5 m), upright growth habit with highly digestible leaves and stems. It is frost-hardy and will continue to provide fresh forage after snowfall. Its crude protein level (on a dry-matter basis) ranges from 19% in September to 15% in late fall.

Seed kale in early June. Kale grows slowly after seeding, so good weed control is essential during the early growing season. The best yields are obtained when kale is drilled in rows 15–70 cm wide at a rate of 2–4 kg/ha. Do not plant kale seed deeper than 1.5 cm deep. Kale can be broadcast seeded at an increased seeding rate of 6 kg/ha. It requires approximately 80–120 kg nitrogen/ha and grows well if manure is used.

Forage Rape

Two main types of forage rape are used for pasture. The broadleaf or giant types are leafy and upright growing and are best pastured by cattle or sheep. Dwarf types are shorter and branching, and may be used for fattening lambs. Do not confuse forage rape with oilseed rape or canola.

Rape poisoning can occur if stunted, low growing, purple-coloured plants are pastured.

Seed rape in early July for grazing from September to November. For maximum yields, drill rape in 50–70-cm rows at 2 kg/ha. Rape can be broadcast seeded at 6 kg/ha, but yield will be lower. Rape requires 80–100 kg nitrogen/ha.

When cattle are grazing rape, always have dry feed present to prevent cattle from eating large quantities of rape at any one time. Make sure cattle are full before putting them out to graze rape the first time.

Cattle can bloat on rape.

Forage Turnips

Forage turnips, also called stubble turnips, fall turnips, white turnips or Dutch turnips, produce a thick mass of bushy tops and large white roots. The animals will first graze the tops off the turnips and then graze the area a second time, feeding on the roots. The roots are high enough out of the ground that animals can get to them easily. Strip grazing is recommended to make best use of this crop. Plant turnips the same way as rape, and fertilize with 100 kg nitrogen/ha. Despite the fact that animals can use both roots and tops, turnips are still lower yielding than rape or kale crops.

PERENNIAL PLANT SPECIES FOR PASTURES

Legumes

Birdsfoot Trefoil

Birdsfoot trefoil has leaves composed of five small leaflets on fine stems, 60–90 cm tall. The leaves are distinct, consisting of two leaflets close to the stem, separated from the other three by a definite stalk. Trefoil flowers from June to September, producing clusters of bright yellow to orange-yellow flowers. The roots consist of one deep taproot with many branching side roots near the surface. Under close grazing, trefoil takes on a recumbent growth habit and produces many small leaves, making the plants look smaller than mechanically harvested plants or infrequently grazed plants. In fact, the yields will probably be the same, since the lower-growing plants produce more leaves.

Trefoil is adapted to good soils but will grow on soils where marginal pH or drainage limits other legumes. It is productive from mid-June to fall and can be stockpiled for late fall grazing. The feed quality is still good later in the season, as trefoil does not lose its leaves when frosted. If 10 cm of growth is left at all times, trefoil can be grazed frequently or can be grazed closely and rested for 30–40 days.

Trefoil grazed closely during the grazing season should not be grazed during the critical fall harvest period identified for alfalfa crops. This 6-week period is needed by the trefoil plants to store sufficient carbohydrates to allow the plants to overwinter and grow well in the spring. If trefoil is grazed during the critical fall harvest period, either leave it to grow to 20 cm or just lightly graze it the following spring.

Trefoil is an excellent legume for pastures because it **does not cause bloat** and can remain productive for many years if allowed to reseed. Trefoil will reseed itself if:

- areas are left ungrazed and the plants allowed to go to seed, or
- the stands are rotationally grazed with 10 cm of growth left at all times

The palatability of trefoil varies because of tannin, a bitter-tasting compound. Tannin levels differ between varieties of trefoil, with some having much more than others. In all varieties, tannin levels increase when the plant is under stress.

Trefoil seedlings are not competitive, making them slow to establish. Trefoil may be thin in first-year stands but thickens with time. Spring growth is also slow, but mid-summer yields are good if it is not overgrazed early in the season. Trefoil does quite well when established by frost seeding (see Chapter 3, *Pasture Improvement*).

Trefoil seed contains a higher percentage of hard seeds (seeds that are slow to germinate), resulting in the germination of the seeds being staggered over a long time and many plants escaping late-spring killing frosts. Trefoil cannot be established into stands that already contain Kentucky bluegrass. Evidence indicates bluegrass produces a chemical toxic to trefoil seedlings.

White Clover

White clover has stems that creep on the ground with erect or upward-slanting branches. Leaves consist of three rounded, stalkless leaflets with shiny undersides and leaf edges that may have a few shallow teeth. The flowers form a spherical head and are usually white but may be pink-tinged. Roots are shallow and fibrous and develop from the nodes of the creeping stems (stolons). Three types of white clover are used in Ontario. They look similar but differ in size.

The intermediate types are more suited for pastures than the ladino and tend to have more stolons per square metre than the ladino varieties.

White clover is adapted to soils that range from well-drained to those with some drainage problems. Its shallow root system limits production on excessively drained soils and during droughty periods. White clover roots generally grow to the same depth as roots of commonly used grasses, creating intense competition between white clover and the grasses for soil nutrients and moisture. White clover often disappears from pastures because it cannot compete with the grasses for nutrients present at low levels. Grasses growing with white clover receive approximately 200 kg/ha nitrogen over the grazing system.

If rotationally grazed, white clovers produce very palatable forage for the full season. Grazing trials headed by Dr. Jock Buchanan-Smith, University of Guelph, found that the legume content would rise from 20%–50% of the stand over the grazing season, and bloat was not a problem with white clover at that level. The general recommendation is that bloat may be a problem if susceptible cattle are introduced to a white clover–dominant pasture at the start of the grazing season or switched from a grass pasture to a heavy legume pasture at any time during the pasture season.

- **Wild white clover** is the smallest, ranging from 5–17 cm tall.
- **Intermediate white clover** (also called Dutch or New Zealand White) grows to 40 cm.
- **Ladino clover** can grow up to 60 cm.

White clover is a short-lived perennial that will reseed if not grazed severely. It can be frost seeded to maintain its presence in the stand.

Red Clover

Red clover has leaves consisting of three stalkless leaflets on tall plants (15–60 cm) with large rose-purple to magenta flowers. Stems and leaves are hairy. Red clover has a weak taproot with many fibrous, side-branching roots. There are two types of red clover: single cut (mammoth) and double cut (medium). Single cut is taller, coarser, later to flower and slower to regrow after grazing than double cut.

Red clover tolerates imperfect drainage and lower pH levels. It is productive in the first year but tends to thin over winter, resulting in lower yields in succeeding years. Red clover has traditionally been thought of as a short-lived perennial, with the older varieties and plants from common seed living just 2–3 years beyond the seeding year. Newer varieties are promising to be longer-lived. Red clover is very competitive and easy to add to a stand by frost seeding. When seeded in mixtures, red clover can suppress the establishment of other legumes because of its competitive nature.

Red clover can cause bloat. Use pastures and hay aftermath with more than 50% red clover carefully. Red clover can contain compounds with an estrogenic effect on the reproductive cycle of sheep.

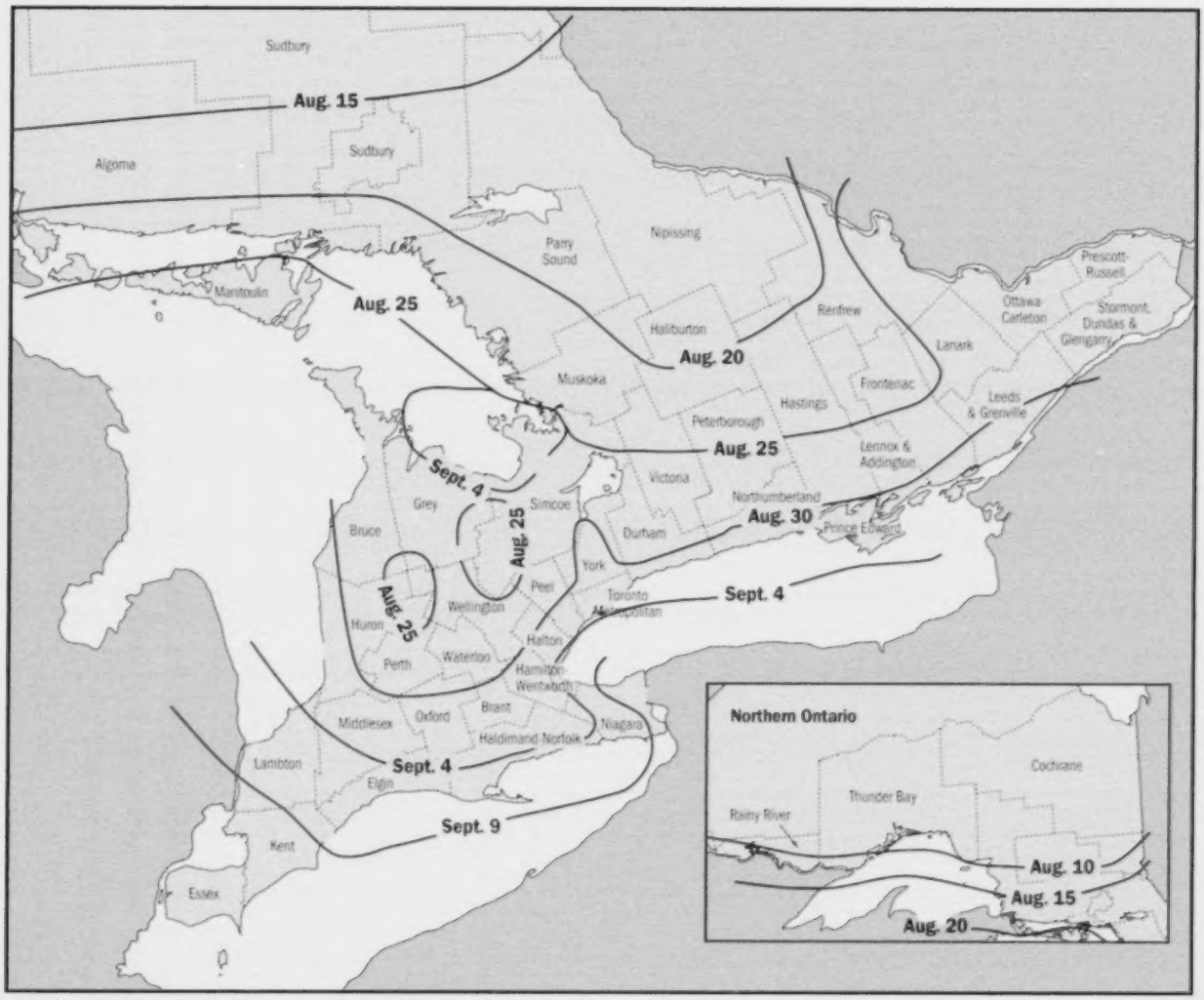


Figure 1–2. Start of the critical harvest period for alfalfa.

Kura Clover

Kura clover has been tried in Ontario, but establishment has proven to be a big challenge.

Kura clover is a very winter-hardy species that is adapted to a wide range of soil conditions, including imperfect drainage, low fertility and lower pH soils. It spreads by rhizomes (underground stems) and has an extensive root system. The initial spring growth consists of upright stems, each with a large white-pink flower. The regrowth consists of leaves and petioles that originate from crowns. The leaves are more pointed and larger than those of other clovers.

Alfalfa

Alfalfa is a tall-growing plant, 60–100 cm, with hollow or solid stems. Leaves consist of three leaflets that are two to three times longer than wide, with serrated tips. The flowers are usually blue or purple but may be yellow or white. The roots can be tap, branching tap, rhizomatous or creeping, but most varieties grown in Ontario have taproots.

When growing conditions are good, alfalfa is the most productive of the legumes. It requires well-drained (or tiled) soils with a pH of 6.2 or above, plus good fertility. Under less than ideal conditions it is susceptible to root diseases and winterkill. Alfalfa is productive for the entire growing season but should not be harvested during the critical fall harvest period (see Figure 1–2. *Start of the Critical Harvest Period for Alfalfa*).

Alfalfa greatly increases the carrying capacity of pastures, however, its use should be limited to highly managed pastures. Graze alfalfa when it is 30 cm high and graze it down to 5 cm. Leaving more residual height actually slows regrowth and lengthens the time required for alfalfa to grow back. Standard alfalfa normally requires a rest period of 30–35 days between grazings, whereas creeping-rooted alfalfas may require a 45–50-day rest period. In most Ontario pastures, creeping rooted alfalfas will not show the creeping behaviour.

Alfalfa that is closely grazed throughout the season or not allowed to reach at least 25% bloom will eventually have extremely low carbohydrate levels. Carbohydrates are needed by alfalfa to survive winter. Even with a fall rest period, if carbohydrate levels get too low, it is impossible to restore them to the level needed, and you will see increased winterkill in that stand.

Alfalfa plants are sensitive to physical damage from the hooves of grazing animals. To reduce the chance of hooves slicing the crowns of the alfalfa plants, keep animals off the field when the ground is soft. When used in pastures, alfalfa does not usually last more than 3 years. However, there are new varieties bred for improved persistence when grazed that have a lower crown set than the majority of the recommended varieties for Ontario and produce an extra 10%–13% of alfalfa after 3 years of grazing.

Bloat is a concern with alfalfa-based mixtures, especially when alfalfa is in the pre-bud stage, since the plant's digestibility is high and fibre content low. Follow the recommendations for bloat control found in Chapter 7, *Animal Health Problems.* Alfalfa suffering from severe insect or disease damage can cause photosensitivity in livestock and may have an estrogenic effect on sheep.

Alsike Clover

Alsike leaves have three stalkless leaflets with fine serrations on the edge borne on smooth slender stalks. The stems may be upright, up to 50 cm, or prostrate, bearing distinctive white and rose flowers. The roots consist of a shallow, branching taproot. Alsike will grow on soils that range from wet and acid, to soils that are well drained and neutral.

Alsike produces most of its growth in June. **Performance is not consistent from year to year, and adding alsike to a mixture usually lowers yields.**

Alsike can cause photosensitivity and liver damage in horses, as well as bloat in ruminants. It is not normally recommended for pasture mixtures.

Sweet Clover

Sweet clover is a tall, up to 2 m, branched, coarse plant that is not a true clover. Its leaves have three oblong leaflets with serrated edges. Both stems and leaves have a distinctive sweet odour when crushed. The flowers, white or yellow, are in numerous long, loose flower arrangements called racemes. Sweet clover's main advantage is its deep taproot. It is ideal on land that needs a deep taproot to break up a hardpan. It grows on infertile soils, provided the pH is near neutral or higher.

Crown Vetch

Crown vetch has coarse, hollow stems that grow 30–150 cm long and are semi-reclining. It will not climb like a vine because it does not have tendrils. Overall height is about 70 cm. The compound leaves are made up of 5–25 pairs of narrow, oblong leaflets. The whitish-pink to purplish-pink flowers are borne in a cluster at the tip of a long stalk in a crown-like arrangement. The plant has a deep taproot with many side-branching roots.

Crown vetch requires well-drained, fertile soils. It is usually difficult to establish but is long lived once begun. Crown vetch needs warm temperatures to germinate, usually late May or June. The young seedlings are not vigorous, making crown vetch susceptible to competition from earlier and more vigorous growing plant species.

Crown vetch's deep branching root system makes it a good choice for stabilizing steep slopes and preventing erosion. Seed is expensive. See Table 1–1. *Dry Matter Yield of Crown Vetch on Shallow Soil Pastures.*

Table 1–1. Dry Matter Yield of Crown Vetch on Shallow Soil Pastures

LEGEND: — = no data available

County	Yield (kg/ha)				
	Seeding Year	Year 1	Year 2	Year 3	Year 4
Leeds	1,969	4,645	2,945	2,873	2,580
Wentworth	1,971	7,022	—	—	—
Lennox & Addington	1,971	5,554	3,460	—	—

Yields are from one cut only.
Source: Watkin, E.M., and J.E. Winch. *An assessment of shallow soil pastures in Ontario.* A.R.D.A. Project Report #85045.

Black Medic, Hop Clover and Tufted Vetch

These three legumes often appear in pastures having been sown in the recent past. Like other legumes, they provide nitrogen to surrounding grasses and have good-quality feed value. The drawback is an extremely low yield.

Grasses

Orchardgrass

Orchardgrass has become the most recommended grass for pastures — it is high yielding, has good distribution and can withstand grazing. However, it is not suitable for every location and does require intensive management.

Orchardgrass is an aggressive, light green bunchgrass. It has long, wide leaf blades and a coarsely tufted panicle. The cross-section of the stems is oval-shaped.

Orchardgrass requires well-drained soils with good surface drainage. It is normally ready for grazing by late April or early May. Start spring grazing when the orchardgrass is 4–5 cm tall. It will remain productive for the full season if moisture conditions are good and the stand is rotationally grazed.

Graze heavily with an 18–25-day rest period in the summer. A longer rest period is needed if the orchardgrass is allowed to mature before grazing. Graze orchardgrass lightly in the fall to remove thick growth that could lodge and cause winterkill. Orchardgrass will winterkill, on average, one year out of four.

Orchardgrass is known for being unpalatable, especially with mature plants. Feed quality also quickly declines as the plants mature. For grazing, it is best if orchardgrass is prevented from heading out. Late-maturing orchardgrass varieties are easier to manage than the fast-maturing earlier varieties. If left ungrazed, orchardgrass forms tough, unpalatable clumps.

Orchardgrass responds very well to high rates of nitrogen fertilizer. Take caution because orchardgrass accumulates nitrates easily, which can lead to nitrate poisoning. To reduce risk, limit mid- or late-season nitrogen applications to 85 kg/ha. See Chapter 7, *Animal Health Problems*, for more details. Grass tetany is a concern on early pastures dominated by orchardgrass, as the grasses may not have sufficient levels of magnesium to meet animal needs.

Smooth Bromegrass

Smooth bromegrass is a tall grass, varying in colour from light to dark green. Leaves are long, wide and flat with a pointed tip and a "W" marking on the leaf. Roots have blunt, brownish rhizomes that allow the plant to spread to form an open sod. The inflorescence is a large spreading panicle, similar to oats, giving rise to the older name of "oatgrass." With deep fibrous roots, brome adapts to well-drained or droughty soils.

Drain fields well to prevent animal foot problems and forage damage during early grazing. Smooth bromegrass is most productive during spring and fall, with mediocre-to-good mid-season production.

Smooth bromegrass is best suited to rotational grazing where it can be grazed heavily in the spring, lightly in the summer and heavily again in the fall. It tolerates continuous grazing with low stocking rates, but summer productivity will be low and fall growth will be lowered. When rotationally grazed, bromegrass should be eaten down to a height of 10 cm and then allowed to recover. In the summer, this usually takes 30–35 days. It is suitable for mixtures with birdsfoot trefoil. The bromegrass can be grazed early, allowing the trefoil to grow and provide pasture for the summer.

Bromegrass is palatable and keeps its nutritional value better than most grasses, giving pasture managers more flexibility in grazing schedules. Late June production could be stockpiled for use in August.

Smooth bromegrass has a very large, light, fluffy seed. This causes seeding difficulties when planting with many types of seeders. If using the grain box, make sure the seed is not planted too deeply — less than 2 cm deep is ideal. Once established, bromegrass is a good competitor that can compete with legumes on low-potash soils.

Meadow Bromegrass

Meadow bromegrass is a reduced creeping type of bromegrass that regrows quickly after being grazed. It has more basal leaves than smooth bromegrass. Leaves are light green in colour, slightly hairy and narrower than leaves of smooth bromegrass. With better frost resistance than the smooth type, meadow bromegrass is a better choice for late fall grazing. The inflorescence of meadow bromegrass is similar in appearance to smooth bromegrass. However, seeds are larger, with longer awns, and are slightly hairy. The seeding problems associated with smooth bromegrass can be worse with meadow bromegrass.

Meadow bromegrass can be used wherever smooth bromegrass can be grown. Substitute meadow bromegrass for smooth bromegrass in the recommended mixtures. Adjust the seeding rate for meadow bromegrass upwards to take into account its larger seed size.

Meadow bromegrass is attractive as a pasture species for several reasons. It is a palatable grass that starts growth earlier in the spring than bromegrass, remains productive during the entire grazing season and can extend the grazing season into late fall. It has faster recovery rates after grazing, with its regrowth coming from existing tiller bases, a trait similar to orchardgrass, whereas the regrowth for smooth bromegrass is initiated from crowns and the rhizomes. Meadow bromegrass remains in a vegetative state after first grazing, producing a nice leafy mass for grazing animals (see Figure 1–3. *Amount and Distribution of Dry Matter From Pastures Differing in Trefoil Content*).

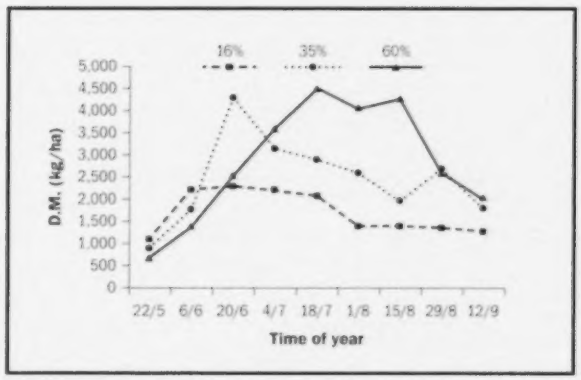


Figure 1–3. Amount and distribution of dry matter from pastures differing in trefoil content.
Source: Dr. Jack Winch, University of Guelph, 1984.

Meadow bromegrass is best used in rotational grazing schemes. Delay grazing until the meadow bromegrass is 20–25 cm tall and have the animals graze it down to 10 cm within a week. A longer grazing period can let animals graze any regrowth and weaken the pasture. Remove animals and allow pasture to grow back to 20 cm in height.

Reed Canarygrass

Reed canarygrass is a tall, up to 2.5 m, coarse grass with rhizomatous roots that form a loose sod. It is easily distinguished by its wide leaves. The inflorescence is a panicle similar to orchardgrass but with finer tufts.

Reed canarygrass is very widely adapted. It tolerates excessive soil moisture, including prolonged flooding or grows on droughty soils. While it also tolerates a low soil pH and poor fertility, it does best when grown on well-drained, fertile soils. It is ready to pasture early in the season and remains productive if kept vegetative.

Reed canarygrass has typically been seeded on wet pastures where animals could not graze until the grass was well past heading and producing seed. It can be the basis of a productive, drought-resistant pasture if seeded on well-drained soils where it can be pastured on a quick rotation for the full season. Reed canarygrass develops coarse stems and leaves, loses palatability and digestibility quickly, once it heads. Time grazing to keep the plants vegetative (not exceeding 30 cm of growth at any time). Reed canarygrass can be used with any of the legumes.

It is slow to establish and is not aggressive in the seeding year. It may take up to 3 years to get a strong reed canarygrass presence in a pasture. Older varieties of reed canarygrass contain alkaloids, which depress animal performance. Most current recommended varieties are free of undesirable tryptomine and carboline alkaloids. Palatability of the new reed canarygrass varieties is excellent, and animal performance is good.

Timothy

Timothy has soft, light-green leaves with wide, medium length (7–25-cm) blades. The head is a distinctive, very dense, spike-like panicle. It has an onion-like bulb or corm at the base of the stems and a shallow root system. It is a non-aggressive bunchgrass with limited tillering ability.

Timothy is widely adapted to heavier soils, variable drainage, fertility and pH. It is most productive in the spring, followed by lower mid-season productivity and little fall growth (see Figure 1–4. *Percent Timothy in the Second Production Year*). Earlier varieties produce slightly more regrowth than later maturing varieties. The shallow root system makes it very susceptible to drought and high temperatures.

To maximize production, allow timothy to reach the boot stage before the first grazing. For this reason, and the lack of mid-summer production, timothy is not an ideal pasture grass. It is best used in mixtures where the first cut is harvested for stored feed and the aftermath grazed. Timothy is commonly added to pasture mixtures because it is a grass most producers are familiar with and is easy to establish.

Creeping Red Fescue

Creeping red fescue is a short plant with narrow, bristly, dark-green leaves. On older leaves, the basal leaf sheaths are a reddish-brown, giving the plant its name. The roots are rhizomatous and form a dense sod. The inflorescence is a fine, open panicle.

Creeping red fescue grows and spreads on most soils, including fertilized subsoils. It grows throughout the entire season and retains good nutritional value in the fall. Productivity is limited, as the grass is short and most varieties were developed for turf or soil conservation purposes.

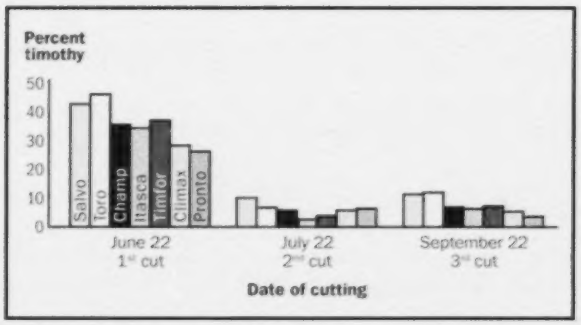


Figure 1–4. Percent timothy in the second production year.

Creeping red fescue is best used for streambank or grassed waterway protection, as the roots hold the soil while the thatch of top growth slows water movement and protects the soil surface. These characteristics also make it a good "bottom" grass — a species added to the mixture to give turf qualities to the forage. As such, add it to mixtures for exercise yards, laneways and wet fields damaged by animal traffic in rainy periods.

Tall Fescue

The leaves of tall fescue are dark green and ribbed with wide, long blades and sharp, pointed tips. This deep-rooted, tall, coarse-growing plant forms tussocks if it is not grazed or cut after several years. It is basically a bunch grass, but frequent grazing will produce a tough sod resistant to trampling damage.

Tall fescue is adapted to most soils, including those with imperfect drainage. Spring growth is slow, followed by steady production throughout the season. It fits well into a rotational grazing system and is an ideal partner with birdsfoot trefoil for providing season-long forage. It can be rotationally grazed up until late June–early July and then left to stockpile in late summer for fall grazing. Research at the New Liskeard Research Station has consistently shown that the fibre levels of tall fescue are lower than all other grasses in the fall (see Table 1–2. *Total Digestible Nutrient Content of Five Grass Species*).

Table 1–2. Total Digestible Nutrient Content of Five Grass Species

Harvested in early November at New Liskeard.

LEGEND: — = no data available

	Total Digestible Nutrients (%)		
Grass Species	**1994**	**1995**	**1996**
Tall fescue	61.4	61.5	59.2
Reed canarygrass	56.7	57.2	54.1
Smooth bromegrass	58.4	58.0	55.9
Meadow bromegrass	54.5	57.3	55.1
Orchardgrass	56.2	—	—
Average	**57.4**	**58.5**	**56.1**

Source: Alternate Forages for Hay, Silage and Pasture. Jim Johnston. Forage Feeds Profit — 1997 Ontario Forage Council Conference.

Tall fescue is useful for erosion control and protection of fragile lands. Its deep roots, long-lived perennial nature and tolerance to marginal conditions allow it to establish and survive on most areas where permanent cover is required.

A seed-borne fungus (an endophyte) has been linked with reduced animal performance on tall fescue pastures. Once introduced to the stand by infected seed it cannot be removed. If cattle, sheep and other livestock graze on large amounts of infected tall fescue, their health may be compromised. Cattle may also be more sensitive to heat stress.

The seed supply of recommended varieties of tall fescue is basically endophyte-free, and animal health problems should not be a concern. Palatability, or the lack of it, is also associated with this grass. Use endophyte-free seed to reduce palatability problems. Palatability is also better in the fall with the onset of cooler weather and frosts. Tall fescue hay is palatable to cattle and sheep.

Remove pregnant horses from fields with infected tall fescue 30 days prior to foaling. See Chapter 7, *Animal Health Problems*, for more information.

Meadow Fescue

Meadow fescue has bright green leaves with narrow, long (up to 50-cm) blades and sharp-pointed tips. Leaves are dull on the upper sides and shiny on the undersides. Meadow fescue is a bunch grass with short rhizomes that give it a weakly creeping habit.

Meadow fescue grows best on deep, fertile soils but will tolerate variable drainage and low fertility. It has a shallower root system, is shorter lived and is not as tolerant of poor conditions as tall fescue. Meadow fescue is most productive in summer and fall, and maintains feed quality into the cooler fall months.

It fits well with trefoil to give summer and fall grazing. This allows it to be used on fields that tend to be wet in spring and cannot be grazed until later in the season.

Meadow Foxtail

Meadow foxtail resembles timothy but has smaller, ribbed leaves. It is a shorter plant and heads out much earlier than timothy. Roots are shallow and fibrous.

Meadow foxtail tolerates poor drainage and low pH. It is extremely early, with most fields heading out by early May. Once headed out, it is very unpalatable. Meadow foxtail is the earliest pasture species but is often seeded on fields too wet to carry animals at the time grazing should start. The shallow roots contribute to low production during periods of high temperatures and drought. It is best used mixed with species that produce through the summer.

Meadow foxtail seed is light, fluffy and hairy, making it difficult to seed. Use coated seed to avoid problems at seeding.

Bluegrasses

Kentucky bluegrass is a dark-green grass with long narrow leaves. Blades have a boat-shaped tip and shiny undersides. It grows 30–100 cm tall with an open, fine panicle. Kentucky bluegrass forms a dense sod on fertile soils.

Canada bluegrass is a bluish-green grass with shorter leaves with boat-shaped tips. The plant is shorter than Kentucky bluegrass with a similar open, fine panicle. Canada bluegrass forms an open sod and is found on less fertile soils.

Both bluegrasses have a dense but shallow root system that limits summer productivity where water is limited. Bluegrass grows most strongly in spring and must be stockpiled for midsummer production. Early growth is palatable, but total production is limited.

Bluegrass withstands animal traffic and can be added to a mixture for areas where high resistance to trampling damage is needed or as a bottom grass in horse pastures. The dense root system and thatch from bluegrasses provides a good cushion for horse's hooves and legs. These grasses, especially Kentucky bluegrass, form the basis for the dark green lawns for display paddocks.

Perennial Ryegrass

Perennial ryegrass is a soft, fine, bright-green grass. Leaves are narrow and short, with ribbed tops and smooth, shiny undersides. It produces a lot of tillers and is 30–60 cm tall with an inflorescence composed of a slender stiff spike with each spikelet edgewise on the central axis.

Perennial ryegrass requires well-drained, fertile soils. It is easy to establish and competitive in mixtures.

It grows quickly during periods of cool, wet weather, making it most productive in spring and fall. During those periods, perennial ryegrass regrows quickly, enabling frequent grazing of a highly palatable and digestible forage (see Table 1–3. *In-Vitro Digestibility of Two Grass Species*). It cannot tolerate hot or dry conditions and is unproductive in summer. It is suited to rotational grazing where other species are available for summer grazing.

Table 1–3. In-Vitro Digestibility of Two Grass Species

Collected from rotationally grazed pastures at Elora Research Station, 1990.

Species	June	July	August	September	Average
Perennial ryegrass	82.5	79.8	77.6	79.4	**79.8**
Orchardgrass	79.0	76.7	73.6	75.4	**76.0**

Source: Alternate Forages for Hay, Silage and Pasture. Jim Johnston. Forage Feeds Profit — 1997 Ontario Forage Council Conference.

If irrigation is possible, consider pure stands of perennial ryegrass. Ryegrass responds well to nitrogen fertility, and the resulting yields could warrant the cost of irrigating. Do not apply nitrogen after July on the forage types of perennial ryegrass. This appears to lower their overwintering ability — a problem associated with perennial ryegrass in Ontario.

Graze or cut off any fall growth before winter to lessen the likelihood of snow moulds developing and damaging the ryegrass.

Redtop

Redtop has dark green leaves with a purplish inflorescence that turns red as it opens. It has fine leaves and stems that are both upright and creeping. Redtop forms a loose sod.

Redtop is tolerant of very low fertility, low pH and poor drainage but does not yield well. It is not competitive on fertile soils and often disappears if soil conditions are improved. Productivity and feed quality are lower than with timothy. Redtop can be used on ditchbanks or grassed waterways where its tolerance to wet soils and sod-forming habits reduce erosion.

2. Establishing Pastures

Successfully establishing a new pasture requires planning and good management. A thick, vigorous stand forms the basis of a productive pasture.

SOIL TEST

The first step in establishing a new pasture is determining:

- existing fertility levels
- pH of the soil to be seeded

Do a soil test the year before you plan on seeding. This gives enough lead time to adjust the pH levels, if necessary. Lime reacts slowly and is best incorporated into the soil 36 months before seeding. If the soil is not worked, the lime will take a couple of years to move into the root zone.

Soil sampling must adequately represent the entire field.

- Take 1 to 2 cores per hectare with a composite sample representing no more than 10 ha of similar soil grouped together.
- Use a sampling tube or spade, sampling the soil to a depth of 15 cm.
- Mix the cores together in a clean plastic bucket to get a representative sample from that area.
- Send the sample to a soil-testing laboratory and request the basic test accredited by OMAFRA. This lists the soil pH, buffer pH, and phosphorus, potassium and magnesium levels in the soil, as well as recommends fertilizer rates that will produce the highest economic yields. See ontario.ca/livestock for a list of accredited soil labs.

Separately sample areas that are significantly different, e.g., sandy knolls in a heavier field or low spots. This allows you to tailor fertility practices to the needs of the soil. Grid or intensive sampling, using global positioning system (GPS), is available. With this method, a farm is divided into small blocks (usually 1 ha) and sampled to allow for precision farming.

SELECTING A SEED MIXTURE

Growing Conditions

Select a seed mixture that is adapted to the growing conditions in the field. Consider drainage, soil pH, natural fertility, soil depth and texture. Figure 2–1. *Soil Drainage Requirements of Forage Species* shows the tolerances of the major forage species to drainage conditions. This is the most important factor to consider because it is the most difficult or expensive factor to change. Figure 2–2. *pH Range for Forage Species* shows the pH range for good growth of different species.

It is important to consider how early in the season the area to be seeded is usually accessible and workable.

- Orchardgrass, meadow foxtail or meadow bromegrass are ideal for fields that dry quickly and are accessible early in the pasture season. These fast-starting grasses can advance the normal grazing season, but the first two become unpalatable and of poor feed quality if allowed to mature. Once ready to be grazed, the animals must have access to them.
- Mixtures based on reed canarygrass are also ideal for early land.
- A trefoil-based mixture with a grass such as tall fescue, bromegrass or timothy is suitable for fields that are slow to dry.

Purpose of the Mixture

The species in the mixture and the proportion of each species depends on the use of the mixture: hay-pasture, permanent pasture or exercise area. Species such as bromegrass, timothy, orchardgrass, tall fescue, reed canarygrass, alfalfa and trefoil provide good hay yields as well as pasture. Shorter-growing species, such as the bluegrasses, creeping red fescue, redtop and white clover, are not suitable for hay but are useful in pastures or exercise paddocks.

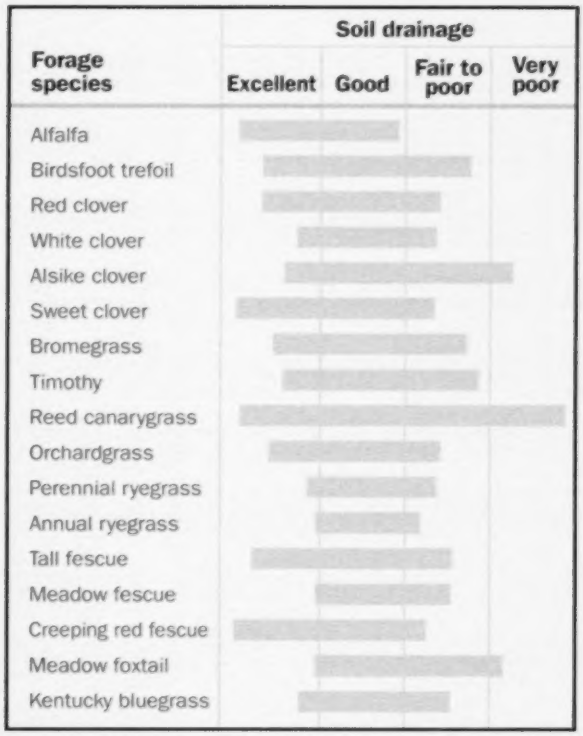


Figure 2–1. Soil drainage requirements of forage species.

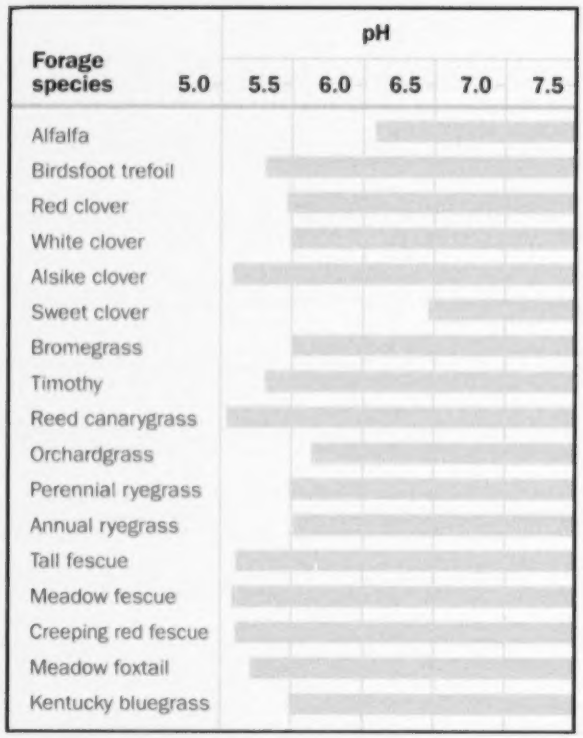


Figure 2–2. pH range for forage species.

Composition of the Mixture

Legume-grass mixtures are preferred for seeding pastures because they:

- produce higher animal gains and milk production
- do not require nitrogen fertilizer to yield well
- perform better than grass pastures during hot, dry weather

The legume component in the mixture improves the nutritional value of the pasture. The feed quality of legumes is superior to that of grasses and does not decline as rapidly with age. As well, grasses grown with legumes usually contain a higher percentage of crude protein than grasses grown in pure stands. The stimulating effect on the grass is caused by the release of nitrogen compounds from legume roots and root nodules. Bacteria living symbiotically in the legume root nodules use nitrogen from the air for their growth and development. While most of the fixed nitrogen is available to the legume, some is excreted into the soil, becoming available to grasses. When bacteria dies and nodules decompose, additional nitrogen becomes available to the grasses.

Ladino and intermediate white clovers supply relatively high amounts of nitrogen (around 200 kg/ha) to companion grasses, while alfalfa, birdsfoot trefoil and red clover supply smaller amounts (usually 80–140 kg/ha). Nitrogen fixation allows legume-grass mixtures to yield well without adding nitrogen fertilizer. Phosphorus and potassium levels in the soil must be maintained to ensure balanced growth of the legume and grass components.

The success of a forage mixture depends on the correct selection of the legume and grass components. Both must suit the conditions under which the mixture is grown.

Table 2–1. Comparison of Red Clover–Hay Pasture Mixture Yields

Mixture	June Hay (kg/ha)	Aftermath Production (kg/ha)	Total Yield (kg/ha)	Increase Over Red Clover + Timothy
Red clover + timothy	5,868	1,344	7,212	0%
Red clover + alfalfa + timothy	6,874	2,531	8,668	20%
Red clover + alfalfa + timothy + orchardgrass	5,308	2,643	7,952	10%
Red clover + alfalfa + timothy + bromegrass	6,227	2,665	8,892	24%
Red clover + alfalfa + ladino clover + timothy + orchardgrass	5,801	2,912	8,713	21%
Red clover + alfalfa + ladino clover + timothy + bromegrass	6,182	2,553	8,736	21%
Red clover + alfalfa + ladino clover + timothy + orchardgrass + bromegrass	5,622	2,844	8,467	17%

Source: R.S. Fulkerson. *Research Review of Forage Production.* Ontario Agricultural College, University of Guelph. 1983.

Legumes generally have deeper root systems than grasses. This allows access to deeper soil moisture and, in turn, legumes yield better in the summer. This produces a steadier production of forage over the grazing season. Overgrazing damages root systems and destroys this advantage of having a good legume population in a pasture.

Legume-grass mixtures succeed because of their natural, close association due to differences in nutritive requirements and root systems. Complementary grasses and legumes make the best use of climatic, soil and growing conditions.

Grasses grown with legumes:

- reduce the danger of bloat
- increase the possibility of having a thick pasture without weeds
- help to reduce winterkill of legumes. If legumes winterkill, the grasses can be fertilized with nitrogen to provide pasture for the season.

TYPES OF MIXTURES

Complex Mixtures

Early- and late-maturing species and varieties are often combined in complex mixtures to produce a long and uniform supply of pasture over the season. These mixtures are based on the idea that different species and varieties come into peak production at different times in the season. Ideally, this mixture would supply pasture for the entire grazing season. The yielding ability of mixtures and the distribution of that yield are associated with the species in the mixture rather than the complexity of it (see Table 2–1. *Comparison of Red Clover–Hay Pasture Mixture Yields*). **It is important that mixtures be made up of compatible legumes and grasses.** As the number of species in a mixture increases, the opportunity for unbalanced competition among them increases.

It is the right combination of grasses and legumes that makes the difference — not the number of species in a mixture.

Simple Mixtures

Simple mixtures contain one legume with one or two compatible grasses. They are easier to manage over the short term for high yields and give a more predictable level of forage production throughout the season. Two or three simple mixtures planted in different fields can ensure a steady production of forage (see *Suggested Pasture Mixtures*, below).

Suggested Pasture Mixtures (per ha)

Short-Term Pastures (3–4 yr)

Well-drained soil

· Alfalfa	(11 kg)
Orchardgrass	(6 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Timothy	(4 kg)
Bromegrass	(9 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Orchardgrass	(3 kg)
Bromegrass	(9 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Orchardgrass	(2 kg)
· Alfalfa	(11 kg)
Bromegrass	(9 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Bromegrass	(4 kg)
· Alfalfa	(6 kg)
White clover	(2 kg)
Timothy	(2 kg)
Bromegrass	(4 kg)
Meadow fescue	(3 kg)
· Orchardgrass	(9 kg)
White clover	(2 kg)

Moderately well-drained soil

· Alfalfa	(9 kg)
Ladino	(2 kg)
Timothy	(4 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Reed canarygrass	(8 kg)
· Alfalfa	(9 kg)
Ladino	(2 kg)
Meadow foxtail	(10 kg)
· Red clover	(4 kg)
Ladino	(2 kg)
Timothy	(8 kg)
· Orchardgrass	(9 kg)
White clover	(2 kg)

Fair to poorly drained soil

· White clover	(2 kg)
Timothy	(6 kg)
· Red clover	(4 kg)
White clover	(2 kg)
Timothy	(8 kg)

Suggested Pasture Mixtures (per ha)

Long-Term Pastures (5 yr or more)

Well-drained soil

· Trefoil	(9 kg)
Timothy	(2 kg)
· Trefoil	(9 kg)
Bromegrass	(4 kg)
· Trefoil	(9 kg)
Meadow foxtail	(10 kg)
· Trefoil	(8 kg)
Tall fescue	(10 kg)
· Trefoil	(8 kg)
Creeping red fescue	(6 kg)
· Trefoil	(8 kg)
Orchardgrass	(4 kg)
· Trefoil	(9 kg)
Reed canarygrass	(7 kg)
· Reed canarygrass	(9 kg)
White clover	(2 kg)

Moderately well-drained soil

· Trefoil	(9 kg)
Timothy	(2 kg)
· Trefoil	(9 kg)
Bromegrass	(4 kg)
· Trefoil	(9 kg)
Meadow foxtail	(10 kg)
· Trefoil	(8 kg)
Tall fescue	(10 kg)
· Trefoil	(8 kg)
Creeping red fescue	(6 kg)
· Trefoil	(8 kg)
Orchardgrass	(4 kg)
· Trefoil	(9 kg)
Reed canarygrass	(7 kg)
· Reed canarygrass	(9 kg)
White clover	(2 kg)

Fair to poorly drained soil

· Trefoil	(9 kg)
Timothy	(2 kg)
· Trefoil	(9 kg)
Bromegrass	(4 kg)
· Trefoil	(8 kg)
Creeping red fescue	(6 kg)
· Trefoil	(6 kg)
Timothy	(2 kg)
Bromegrass	(5 kg)
Tall fescue	(5 kg)

Complex Versus Simple Mixtures

Management practices and environmental conditions influence the competitive abilities of each species differently. It is not possible to manage a very complex mixture for maximum production of one species without creating conditions that will harm another species. Yield from the species less adapted to the management will decrease, and eventually the species will disappear as the plants die.

A review of the Ontario Forage Mixture Trials by Dr. Ann Clark in the early 1990s shows that, historically, mixtures with four to five components tend to be better over the long term.

No matter what type of mixture is being used, seed mixtures for pastures should have grasses and legumes with similar maturities. Use of different maturities encourages the overgrazing of the younger, late-maturing species and undergrazing of the faster maturing plants.

Type of Grazing Management

The grass and legume species have different tolerances to being grazed. Some, like Kentucky bluegrass, can survive frequent close grazing, while others survive only if grazing is infrequent (see Table 2–2. *Suitability of Forage Species to Different Types of Harvest Management*). Select a mixture where all species fit the grazing management (see *Suggested Pasture Mixtures*).

SEEDING RATES

Use the rates in this publication or in OMAFRA Publication 811, *Agronomy Guide for Field Crops*, available at ontario.ca/crops. These seeding rates are proven to produce good stands under average-to-good growing conditions.

High seeding rates do not produce better yields.

Table 2–2. Suitability of Forage Species to Different Types of Harvest Management

LEGEND: H = Highly suitable
S = Suitable
N = Not recommended

Forage Species	Frequent, Close Grazing	Rotational Grazing	Stored Feed
Alfalfa	N	S	H
Birdsfoot trefoil	N	H	H
Red clover	N	S	H
White clover	H	H	S
Alsike clover	N	S	S
Sweet clover	N	S	S
Bromegrass	N	S	H
Timothy	N	S	H
Reed canarygrass	N	H	H
Orchardgrass	H	H	H
Perennial ryegrass	H	H	H
Annual ryegrass	H	H	H
Tall fescue	N	S	H
Meadow fescue	N	S	H
Creeping red fescue	H	H	N
Meadow foxtail	N	S	N
Kentucky bluegrass	H	H	N

Higher seeding rates do not, as a rule, give more yield. Higher seeding rates are only useful in very poor seeding conditions when high seedling mortality is expected (see *Suggested Pasture Mixtures for Horse Exercise Paddocks* and Table 2–3. *Effect of Seeding Rates on Yields*).

Table 2–3. Effect of Seeding Rates on Yields

Mixture	Seeding Rate (kg/ha)	Dry Matter Yields (5 yr. avg.)	Average Yield
Complex mixture: meadow fescue, Canadian bromegrass, ryegrass, timothy, domestic ryegrass, red fescue, ladino clover, white Dutch clover, Lincoln bromegrass, wild white clover, redtop, Wood's meadowgrass, Kentucky bluegrass, wheat	13.4	4.83 tonnes/ha	4.76 tonnes/ha
	22.4	4.72 tonnes/ha	
	39.2	4.76 tonnes/ha	
Less complex mixture: ladino clover, red clover, alsike clover, timothy, orchardgrass	13.4	4.13 tonnes/ha	4.16 tonnes/ha
	22.4	4.31 tonnes/ha	
	39.2	4.02 tonnes/ha	
Simple mixture: reed canarygrass, birdsfoot trefoil	13.4	7.33 tonnes/ha	7.51 tonnes/ha
	22.4	7.51 tonnes/ha	
	39.2	7.71 tonnes/ha	

Source: Dr. John B. Washko, Department of Agronomy, Pennsylvania State University.

Suggested Pasture Mixtures (per ha) for Horse Exercise Paddocks

Well-drained soil	
· Tall fescue	(6 kg)
Kentucky bluegrass	(10 kg)
White clover	(2 kg)
Moderately well-drained soil	
· Tall fescue	(10 kg)
White clover	(2 kg)
· Timothy	(5 kg)
Kentucky bluegrass	(8 kg)
White clover	(2 kg)
· Timothy	(2 kg)
Creeping red fescue	(6 kg)
Kentucky blue	(3 kg)
White clover	(2 kg)

Seed Quality

Always use good seed when establishing a pasture. Certified seed is your guarantee of quality. Use of certified seed ensures:

- germination
- good seedling vigour
- fewer weed seeds

Select forage varieties using the Ontario Forage Crops Committee test results. These varieties have proven themselves in performance trials to be adapted to Ontario conditions.

Direct Versus Companion Seeding

Make most pasture seedings without a companion crop. The companion crop competes heavily with the establishing forages for light, moisture and nutrients. If a companion crop is needed for erosion or weed control, or required for feed or straw, the following points will help ensure a good forage establishment:

- Use oats seeded at a light rate — less than 60 kg/ha.
- Use an upright oat variety with low tillering ability.
- Harvest the companion crop as silage at the late boot stage or by grazing when it reaches 30 cm.
- Avoid using high-nitrogen fertilizers, or heavy rates of manure, which tend to result in lodging.
- Remove badly lodged companion crops as soon as possible.

Note that white clover can be optional in these mixes if the horse owner does not want to have any clover in the paddock. It will then be necessary to fertilize with nitrogen to promote good grass growth in these paddocks.

LEGUME INOCULATION

Inoculation refers to mixing *Rhizobium* bacteria with legume seeds prior to planting. After germination, bacteria invade the root hairs of the young seedlings forming nodules and allowing the legumes to "fix" nitrogen from the air. Well-nodulated legumes get enough nitrogen through fixation to yield well without nitrogen fertilizer. Each legume species requires a specific strain of *Rhizobium* for nodule formation. Pre-inoculated seed is available, or inoculation can easily be done at the farm. When buying the inoculant separately, check for the expiry date and handling cautions on the package to ensure effective nitrogen fixation. Inoculate legumes just before seeding. Do not mix inoculated seed with fertilizer.

The Seedbed

The most important step in establishing forages is seedbed preparation — a good seedbed is essential for good establishment. The seedbed should be fine, firm and free of weeds. This allows uniform, shallow placement of the seed and even coverage to give good seed-to-soil contact.

Depth of Seeding

Since forage seeds are small, with few energy reserves to grow a shoot to the soil surface, plant forage seeds close to the soil surface, less than 1 cm deep. Seeding too deep is one of the major causes of establishment failures (see Table 2–4. *Seedling Emergence as Influenced by Planting Depth*).

Time of Seeding

Seed pastures in early spring, as cool moist weather is conducive to good establishment. Late spring seedings generally do not establish well. The shallowly placed seeds are vulnerable to dry conditions and one or two warm days can dry the soil surface to a point where seed germination will be stopped. Young plants with small root systems are stressed by hot, dry summer conditions and may die.

Planting forage seeds too deep is one of the main causes of establishment failures.

Table 2–4. Seedling Emergence as Influenced by Planting Depth

	Planting Depth			
Crop	1.3 cm deep	2.5 cm deep	3.8 cm deep	5.1 cm deep
Alfalfa	64%	53%	45%	19%
Red clover	56%	62%	22%	14%
Timothy	89%	81%	39%	12%
Bromegrass	78%	69%	51%	24%

Source: Bob Fulkerson, Ontario Agricultural College, University of Guelph.

Most forages can be seeded in the first 2 weeks of August and still develop well enough to survive the winter if soil moisture conditions are good at the time of seeding. If conditions are dry, germination is delayed until there is adequate moisture. This could mean seedlings may not develop enough to survive winter. Do not seed slow-establishing birdsfoot trefoil, crown vetch and reed canarygrass in early August. They are likely to produce reasonable stands only 1 year out of 10.

SEEDING TECHNIQUES

Cultipacker Seeder

A cultipacker seeder has two corrugated rollers with the seed box mounted between the rollers. The first roller makes a groove into which the seed is dropped. The second roller covers the seed by packing soil around it. Cultipacker seeders do not apply fertilizer. Fertilizer should be broadcast prior to seeding.

Grain Drill and Band Seeding

A drill with a forage seed box can be used quite successfully for seeding forages. Band seeding assures correct placement of both seed and fertilizer. The fertilizer is banded in the soil by the coulters, the seed is dropped on the soil surface 15–25 cm behind the fertilizer and the seed is covered by drag chains or a cultipacker.

New drills (both conventional and no-till) tend to seed in bands. Most older drills can be adapted to carry out band placement. The seed is carried to within 7–10 cm of the soil surface by extended plastic or metal tubes. On some drills, the grass seed box may be remounted on the back of the drill to shorten the length of the seed tubes. The tubes may be rigidly fastened to the furrow opener to drop the seed 10–12 cm behind the furrow opener or, preferably, fed through short pieces of pipe attached to the footboard. Since the tube vibrates less, there is less scattering of seed than when attached to the furrow opener. Reducing tractor speed to 6 km/h or less reduces vibration, places the seed over the fertilizer and improves uniformity of depth of seed placement.

To give the seed a shallow covering, use:

- drag chains
- a chain harrow
- a cultipacker pulled behind the drill or preferably by a small, 6-cm wide packing wheel rolling behind each furrow opener

Packing wheels cause less compaction of the soil surface than other options. Erosion problems are reduced, while germination and emergence are more rapid and uniform.

Plant nutrients are essential for seedling development and growth. The primary nutrient required is phosphorus, as it stimulates early root and shoot development. Small seeded forages need a large, readily available source of phosphorus after germination and benefit from phosphorus banded below the seed. Where adverse weather conditions occur during establishment, a readily available source of phosphorus is critical. Use the rate of phosphorus indicated by the soil test results. If your soil tests very high in phosphorus, it may not be economical, from a yield increase standpoint, to band phosphate.

Apply a small amount of nitrogen, 15 kg/ha, in addition to any potassium required as indicated by the soil test. Additional applications of phosphorus and potassium may be necessary in late summer. Top-dress new seedings, using the results of the soil test as a guide, to ensure good winter survival and top yields in the succeeding year.

WEED CONTROL WHEN SEEDING FORAGE STANDS

Weeds hinder establishment of a productive pasture. Fast-growing weeds can crowd out or smother young forage seedlings. Many weed seeds remain viable in the soil for more than 20 years, making it impossible to have a perfectly weed-free seed bed. Prevent as many weeds from establishing as possible:

- Control weeds such as quackgrass and dandelions with cultural or chemical methods prior to seeding.
- Use certified seed to prevent seeding hard-to-control weeds, and fertilize to encourage good forage growth.
- Use chemicals sparingly. Because pasture mixtures are usually composed of grasses and legumes, there are very few herbicides that are safe to both types of plants but effective against weeds. See OMAFRA Publication 75, *Guide to Weed Control,* available at ontario.ca/crops, for herbicide information.
- Consider clipping to control measure for problematic weeds. Clip the weeds before they set seed. You may need to clip several times if the weeds have large root reserves to support new growth.

3. Pasture Improvement

Pastures that are no longer productive can be improved without plowing. There are two basic approaches to restoring established pastures to a productive state:

- rejuvenation
- renovation

Any pasture improvement that you undertake will require a change in the management of that pasture or it will quickly revert to its pre-renovation state.

CHOOSING THE IMPROVEMENT TECHNIQUE

There are four steps to choosing which technique to use to improve your pasture.

1. **Determine why the pasture is performing poorly.** Look for:

- signs of poor fertility
- overgrazing or undergrazing
- weeds
- the amount and distribution of productive forages
- the amount of unproductive grasses
- bare spots
- thinness or thickness of the sod

If productivity is poor because of the first three signs, rejuvenation is a suitable option. If the sod is thin or full of bare patches, with little in the way of productive grasses or legumes, renovation would be a better choice.

2. **Determine your production goals for the field and how quickly the pasture must be improved.**

In general, rejuvenation is quicker than renovation, and broadcast and sod seeding are faster than improvement methods using livestock. Legume content tends to be superior in renovated fields. These fields require less fertilizer to improve yield and perform better over the entire grazing season than rejuvenated fields.

3. **Determine if there are conditions that limit the choice of either option.** Consider:

- topography
- stoniness
- drainage conditions
- accessibility of field to equipment
- availability of equipment
- erosion potential
- depth of soil

4. **Consider the cost of the different improvement techniques.**

REJUVENATION

Pasture rejuvenation involves using a fertilizer program and controlled grazing to encourage productive forage species to return and dominate a pasture. This approach recognizes that the soil in which pastures grow is often deficient in the nutrients required to support the growth of productive plants. The three major elements — nitrogen, phosphorus and potassium — must be present in sufficient quantity to meet the needs of the desirable legumes and grasses.

The first step in rejuvenating a pasture is taking a soil test to determine the nutritional state of the soil. Apply phosphorus and potassium according to the results of the soil test. Extra amounts of these nutrients have little additional effect on yield (see Table 3–1. *Response of Non-Renovated Pastures to Annual Applications of Phosphorus and Potassium*). While applying phosphorus and potassium can increase the amount of forage produced, it is the application of nitrogen that brings about the largest changes. Nitrogen kills moss, depresses the growth of poor-producing grasses and stimulates the growth of productive grasses. The minimum amount of nitrogen needed for rejuvenation is 75 kg/ha. Nitrogen cannot be effective if either phosphorus or potassium are lacking.

Table 3–1. Response of Non-Renovated Pastures to Annual Applications of Phosphorus and Potassium (3-yr average)

Site	No fertilizer	Half recommended rate	Recommended rate	Twice recommended rate
#36	346 kg DM/ha	664 kg DM/ha	757 kg DM/ha	696 kg DM/ha
#38	692 kg DM/ha	1,063 kg DM/ha	1,075 kg DM/ha	1,230 kg DM/ha
#40	1,620 kg DM/ha	1,944 kg DM/ha	1,963 kg DM/ha	2,081 kg DM/ha
#46	1,551 kg DM/ha	1,549 kg DM/ha	1,903 kg DM/ha	2,287 kg DM/ha

Source: Watkin, E.M., and J.E. Winch. *Assessment and improvement of roughland pasture in Ontario.* A.R.D.A. Projects 25021 and 6011. 1970.

Improving fertility encourages viable seeds in the soil to break dormancy, and unexpected grass, legume or weed species may appear in the stand.

Rejuvenation is a quick way of increasing pasture productivity. It works best on areas with a history of being under-fertilized and undergrazed. Such areas usually contain a small number of productive grasses and legumes among the larger population of native grasses and weeds.

Extra phosphorus and potassium do not always produce higher yields.

Once a field has been rejuvenated, grazing management that includes adequate rest and recovery time for the forage species is key to protecting and fostering the growth of desirable plants. A good fertility program must also be followed every year, or the treated area will revert to the previous unproductive state.

RENOVATION

Pasture productivity can be greatly enhanced by introducing high-yielding forage species. Renovation techniques make this possible without plowing. The success of renovation depends on:

- selecting forage species adapted to the growing conditions in the field, the intended method of renovation and future pasture management
- preparation of the field
- seeding at an appropriate time of year
- inoculating the legumes properly
- moisture conditions at, and following, seeding
- soil fertility at, and following, seeding
- control of competition from the existing plants

Established plants have all the advantages in renovated pastures. New seedlings must be able to survive the competition with the old plants for light, moisture, space and soil nutrients.

Light

Shading seriously affects the growth of legume seedlings. It reduces root growth more than top growth, and inhibits nodulation and nitrogen fixation.

Soil Nutrients

Existing grasses are better competitors for available soil nitrogen, and new seedlings may suffer from nitrogen deficiency. Legume growth and nitrogen fixation are also limited on soils with low levels of phosphorus. Correct nutrient deficiencies with fertilizer.

Moisture

Due to small root systems, new seedlings are vulnerable to water stress. Old plants with larger roots are able to access a larger soil area for available moisture. Renovating in early spring offers a better chance of having good moisture conditions. However, in early spring, soil under a sod stays cooler for a longer period of time than a bare soil. Low soil temperatures during germination and establishment can reduce plant density, nodulation and nitrogen fixation, and seedling growth rates. Early-August growth renovations avoid this problem and can be successful if moisture conditions are good and there are no early killing frosts.

Prior to Renovating

- Cut or graze the area heavily, to weaken existing plants.
- Control problem weeds.
  - Spray the area with an appropriate herbicide in fall, prior to a spring seeding.
- Take soil tests to determine fertilizer requirements.

At Establishment

- Apply a herbicide to kill or suppress the sod when grass growth reaches 5–10 cm, if one was not used the previous fall.
- Inoculate legume seeds just before seeding.
- Seed as early as possible in spring. Make sure the seed is placed at the right depth. If conditions are dry, plant closer to 1.5 cm than 0.5 cm.
- Avoid seeding when the ground is wet. This causes smearing of the slot sides, leading to impeded drainage. The soil at seeding should be moist and friable.
- Fertilize according to need.

During the Establishment Year

- Control competition from the old sod. Keep the old sod grazed down to allow new plants to establish. Graze the old plants when they reach 8–10 cm in height.
- Use controlled grazing management such as rotational grazing to encourage and protect new seeding.
- Fertilize in the fall according to soil test recommendations.

SEEDING INTO THE SOD

Sod seeding has several advantages over conventional seeding. Reseeding can be done in areas not suitable for ploughing, with a minimum loss of time and pasture production. As most of the soil surface remains undisturbed, few annual weeds germinate, and moisture loss from the ground is kept to a minimum.

You can use a no-till drill to place seed into the soil of an existing sod. This method of renovation has the highest chance of success, as the seed can be placed at the proper depth in close contact with soil particles and can readily absorb soil moisture for germination.

Modify the drill by rerouting the seed tubes of the legume seed box so the seed falls into the disk openers. Adjust the disks to place the seed and fertilizer 0.5–1.5 cm deep.

Sod seeders, designed for seeding into sod, normally do a better job of establishing new stands than modified grain drills. There are various models of sod seeders built to handle different sod conditions, different degrees of stoniness and roughness of terrain. Before renting or buying a sod seeder, confirm that it will handle the conditions presented by the field to be renovated.

The type of groove opener on the sod seeder affects the rate of success. There are three basic slot shapes: the "V", the "U" and an inverted "T". The seedling emergence from the V-shape slot created by double disc openers and the torn or shattered U-shape made by hoe openers is improved by press wheels operating directly on the seeds at the base of the groves before covering. This brings the seeds into good contact with the soil. It is important that the grooves be closed to prevent the slot from drying out.

A chisel opener creates an inverted "T" slot in the soil. In dry conditions, this slot design is superior to the other two. Under good moisture conditions, few differences in seedling emergence are seen. Closure of the "T" groove is improved by using either a bar harrow behind the drill or press wheels.

BROADCAST SEEDING

Applying seed on the soil surface of an old pasture is an easy and inexpensive way to reintroduce productive legumes and grasses. This approach makes it possible to improve almost any pasture, regardless of the topography or stoniness. It works best on thin sods with bare ground showing and is more successful on fields that have been heavily grazed prior to seeding.

Broadcast seeding is more risky than seeding into sod for the following reasons:

- **Oversown seeds often have difficulty germinating.** Seed broadcast on top of the soil experience more severe conditions than buried seed. Moisture conditions and humidity levels change quickly at the soil surface, and this rapidly fluctuating environment makes for poor germinating conditions. It is not unusual for less than 75% of oversown seed to germinate.
- **The roots of oversown seeds can have difficulty penetrating the soil surface and growing fast enough to keep up with retreating moisture in the soil under dry conditions.** The primary danger is that the tips of developing roots will be killed. The root tips — the sites at which roots grow — can quickly become desiccated. The roots must establish for the plant to anchor in the ground, absorb water and nutrients.
- **Seedlings are vulnerable to competition from older plants already established in the pasture.** Competition from the existing plants must be controlled by grazing or clipping.

LIMITED TILLAGE

Limited tillage can be carried out on thick sods to improve the chances of a successful broadcast seeding. Disc or harrow the sod so that up to 50% of the sod is killed and bare ground exposed. As previously buried weed seeds are exposed and allowed to germinate, annual weeds become a problem. The success of this method depends on control of existing plants and new weed infestation.

FROST SEEDING

Broadcast seeding when the ground is frozen or subject to frosts is known as "frost seeding." Frost seeding can be carried out from November through to early April and, like broadcast seeding at other times of the year, works best on thin sods. The advantage of frost seeding is that seed is worked into the ground by the freezing and thawing action of the soil. This protects it from poor moisture conditions better than seed broadcast at other times. Melting snow and early spring rains also ensure sufficient moisture for germination. Principal dangers to new seedlings are a late frost and competition from established plants.

Frost seeding can be done on top of snow. In fact, the pattern of sown seed on snow makes it easier to keep track of which areas have been seeded. The seed does not run off with meltwater, and even steep hills can be seeded this way.

Frost seeding is more suitable for introducing legumes than grasses. It works particularly well with birdsfoot trefoil and the clovers. Inoculate the legumes before seeding. Seeding can be done with a cyclone seeder carried on foot or from the back of a snowmobile or all-terrain vehicle.

The "hard seed" (seeds that are slow to germinate taking up to a year or more before they germinate and grow) content in seed lots of legumes usually means the legume population thickens with time (see Table 3–2. *Average Dry Matter Yield of Pastures Renovated With Birdsfoot Trefoil*). Good populations of birdsfoot trefoil are often not seen until the second year following seeding.

Table 3–2. Average Dry Matter Yield (kg/ha) of Pastures Renovated With Birdsfoot Trefoil (from 20 Ontario sites)

	Years After Renovation					
Pasture	**1**	**2**	**3**	**4**	**5**	**6**
Renovated	4,600	4,370	4,200	4,930	5,180	6,520
Unimproved	1,240	1,160	810	1,300	1,720	1,460

Source: Jack Winch. Ontario Agricultural College, University of Guelph.

Birdsfoot trefoil plant populations build with time, which is reflected in yields.

By mid-May, apply potash and potassium according to soil test results and graze the pasture to reduce competition from the established sod.

USING LIVESTOCK TO RENOVATE PASTURES

Cattle can be used to introduce legumes into pastures. These inexpensive renovation techniques improve pastures over a 3–4-yr period. These methods work because the hard seeds found in legume seed lots pass through the animal's digestive tract and remain viable. Quick-germinating seeds are killed.

It takes 24–72 hr for the seed to travel through the digestive tract. The seed will not germinate in freshly excreted feces. The feces must break down first and be thinly distributed on the soil.

Island(s)

Legumes are established in a small area(s), and the animals graze only after seed has set. In the process of grazing, seed is ingested and excreted in some other part of the field. The "islands" should be established at a distance from the water, salt and mineral supply.

Feeding Seed

Legume seeds can be added to any grain being fed or to loose mineral mixes. Mature hay (containing seed) can be used as an alternative, but the amount of seed ingested is relatively small.

Manure

Add 0.5 kg of legume seed to each load of manure spread on old pastures to encourage legume establishment.

FERTILIZING PASTURES

To grow and remain productive, plants require a continuous supply of water, sunlight and nutrients. Fast-growing, productive pastures have high demands for mineral nutrition.

The mineral elements needed by plants are classified as:

- macronutrients (those required in relatively large amounts)
- micronutrients (those needed in smaller amounts)

The three macronutrients are nitrogen, phosphorus (phosphate) and potassium (potash). The 10 micronutrients are calcium, magnesium, sulphur, boron, chlorine, copper, iron, manganese, molybdenum and zinc. Nutrients are supplied to plants from the soil. If the soil does not contain the proper amount and balance of elements, the nutrients can be acquired from manure, fixed from the air by legumes (nitrogen only) or applied as commercial fertilizers. All elements applied to the soil enter the nutrient cycle and may eventually become available to the plants.

Plants must have a healthy root system to use available soil nutrients. Overgrazed plants, with small, weak root systems, cannot take advantage of improvements in soil fertility.

Nitrogen

The lack of nitrogen limits the growth of most pastures more than any other essential element. As a major constituent of plant proteins, nitrogen is necessary for plant growth and metabolism. Plants lacking nitrogen are slow growing, small and light green. Pastures that are nitrogen deficient are unproductive, slow to recover after being grazed and offer a poorer quality feed to grazing animals (see Table 3–3, *Nutrient Removal Values of Common Pasture Species*).

Table 3–3. Nutrient Removal Values of Common Pasture Species

Forage	Base Yield	Removal Base Value (kg/ha)		
		N	P_2O_5	K_2O
Wheat	5 t/ha	101	49	30
Barley	4 t/ha	84	34	26
Oats	2.9 t/ha	62	21	17
Legume forage	11.2 t/ha	352	73	336
Mixed forage	11.2 t/ha	314	73	336
Grass forage	11.2 t/ha	196	56	196

Adapted from *The Value and Application of Manure on Forages*, OMAFRA.

Ideally, nitrogen should be supplied to a pasture from the fixation of nitrogen in the air by bacteria living in nodules on the roots of legumes. This source of nitrogen is continuous throughout the growing season, provides all the nitrogen required by the legumes and some for the grasses, leaves overwintering nitrogen in a non-leachable organic form and is low priced. Pastures with a legume content greater than 50% require no additional nitrogen for good yields. A small amount (25 kg/ha) of nitrogen can be used on legumegrass pastures in the spring in order to get the grass off to a fast start and provide early grazing.

As grass content in a pasture increases, so does the need to add nitrogen, in a readily available form, either as manure or commercial fertilizer.

Using several small applications of nitrogen rather than one large one will obtain high yields from grass pastures more efficiently. Frequent applications also produce a more uniform distribution of yield over the grazing season. Even in seasons with a dry period, production is better when nitrogen is applied two or three times, rather than in one large application. Nitrate poisoning is a potential hazard when grasses receive nitrogen prior to a period of poor growth (see Chapter 7. *Animal Health Problems*).

The minimum amount of nitrogen needed to produce a yield response is 50 kg/ha.

Do not apply more than 75 kg/ha per application. Applications above this rate increase the chance of nitrate poisoning, particularly if the nitrogen is applied in summer or fall.

Fast-growing plants make the best use of applied nitrogen. Demand for nitrogen is highest in the spring and immediately after grazing. Apply nitrogen within 1 week of grazing. In rotations with short rest periods (less than 30 days), use smaller nitrogen applications since the grass does not have enough time to efficiently make use of large amounts of nitrogen.

Manure on Pastures

Manure can be used on pastures. Its effectiveness depends on:

- when it is applied
- application rate
- uniformity of the application

Apply manure when plants are small and ready to grow quickly. Early spring is best, but fall is usually most convenient. Spread manure thinly. Clumps of manure, like manure pads, smother small plants or shoots. Animals may refuse to graze the treated area if manure is applied during the growing season. To prevent selective grazing, treat the whole pasture with manure. Over-application of manure, as with other sources of nitrogen, can cause nitrate poisoning or grass tetany.

Do not use hog manure on sheep pastures because of the possibility of copper toxicity.

Phosphorus

Plants require phosphorus to support new growth and good root development. Requirements for phosphorus are highest during seedling development and initiation of growth. Established plants with phosphorus deficiency show purpling of upper leaves. This is often seen in grasses in early spring. The cool, wet soil retards root growth, and the plant is incapable of extracting sufficient phosphorus from the soil. The leaves turn purple along the margins and tips.

Deficiency symptoms at this time may be more of an indication of the weather than an actual deficiency in the soil. An annual application of phosphorus to an established pasture is an efficient method of overcoming a phosphorus deficiency. Supply phosphorus in an inorganic form, such as commercial fertilizer, or from slow-releasing ground rock phosphate. Manure is not a good source of phosphorus. Grasses are unable to make use of added phosphorus unless there is an adequate supply of nitrogen.

Seedlings deficient in phosphorus may exhibit a purple colour on new growth. Leaves fail to expand, and the seedlings are not competitive. This can allow other species to dominate the sward at the expense of the planted species. For this reason, it is important to ensure the presence of sufficient phosphorus in the soil prior to establishing a new pasture or when renovating a pasture. Best results are obtained when phosphorus is incorporated at the time of seeding, as phosphorus moves slowly in the soil. Banding phosphorus gives small plants ready access to a good supply of this essential nutrient.

Most Ontario soils are low in phosphorus. Improving soil phosphorus levels results in better plant growth, increased palatability, feed intake and digestibility.

Potassium

Potassium is referred to as the regulating element in plants. It is essential for plant growth and reproduction. The major symptoms of plants grown on low-potassium soils are slower growth and reduced root reserves. On pastures, this results in lower production, as plants do not grow as rapidly in the spring or after grazing. Legumes require high potassium levels; low potassium levels can contribute to legume loss from the pasture.

Some Ontario soils have high levels of potassium, and pastures grown on them require no additional sources. Animal manures are a good source of potassium, and regular applications reduce the need for fertilizer. Apply potassium as part of a spring fertilizer (i.e., 18618) or as muriate of potassium (i.e., 0060) in late summer, to stimulate storage of root reserves.

Legumes (especially alfalfa) can be luxury consumers of potassium. If excessive levels of potassium are available in the soil, plants extract potassium in preference to elements such as calcium and magnesium. Plants with elevated potassium levels and low levels of magnesium can cause grass tetany. If large amounts of potassium fertilizer are required, apply them in the fall to reduce the chance of grass tetany occurring.

Magnesium

Magnesium is a minor element that is sometimes deficient in pasture forage. It is essential to plant and animal metabolism, and deficiency in the plants can result in grass tetany in the animals. This is a concern in spring when grass pastures are growing rapidly and their roots cannot take up sufficient magnesium to maintain normal levels in the shoots. Pastures growing on soils formed from calcitic or acid parent materials are most at risk, but grass tetany should not be discounted during rapid spring growth in pastures on dolomitic limestone. Magnesium is sometimes added to pastures as a fertilizer but is usually applied as dolomitic lime.

Sulphur

Sulphur is a minor element required for plant growth and is deficient in Ontario soils. Plants deficient in sulphur are a lighter green to yellow, with leaf chlorosis. Legumes, especially clovers, are most sensitive to low levels of sulphur. While Ontario soils are deficient in sulphur, plants rarely show deficiency symptoms, as fields receive some sulphur from acid precipitation. Areas of northwestern Ontario (districts of Thunder Bay, Rainy River and Kenora) do not receive sufficient sulphur in this form for good plant growth. Make sure that the nitrogen, phosphorous and potassium levels are adequate in your soils before adding additional sulfur. A plant tissue test is the best indicator of sulfur deficiency. If required, sulfur must be added as a supplement to lime or fertilizer.

Selenium

Selenium is not necessary for plant growth but is required by animals. Ontario soils have very low levels of selenium, and animals eating feeds grown on these soils need more selenium to prevent white muscle disease.

NUTRIENT CYCLING

Not all nutrients in the soil are available to plants. Nutrients may be in organic matter, soil organisms, in freely available chemical forms, tightly bound within the structure of soil particles or bound to the surface of soil particles. This is not static, but rather a dynamic system where soil organisms (earthworms, insects and other invertebrates) digest organic matter added to the soil. Their by-products, as well as their bodies as they die themselves, are in turn digested by soil micro-organisms (fungi, bacteria, etc.). These micro-organisms are, in turn, digested by other micro-organisms or decompose into elements that enter the soil chemistry. Within the chemistry, some elements form tight chemical associations with soil particles while others are relatively available for plant uptake.

Healthy, fast-growing pastures have soil with active organic matter and chemistry as new organic matter is regularly added to the system. With a complex cycle, it is impossible to determine the exact status of the entire system at one time. The level of organic matter in the soil (undigested plant material, macroorganisms and microorganisms) can be measured, as well as the level of nutrients available to plants in the soil.

Test soils regularly to determine the level and balance of various nutrients. This allows you to increase the nutrients at insufficient levels and prevent the over-application of elements currently at satisfactory levels. Keep records and use soil tests as a management tool. They show, over time, which elements are increasing or depleting. Changes can then be made to the fertility program to prevent the depletion of nutrients and the "run-down" pastures that result.

SOIL TESTS

A basic soil test measuring pH, phosphorus and potassium levels is sufficient for most pasture management. Soil tests for northwestern Ontario should include sulphur testing. Further tests may be beneficial if a specific deficiency is suspected but are not required on a regular basis. See www.ontario.ca/livestock for a list of accredited soil-testing laboratories in Ontario.

Fertility Program

Apply phosphorus and potash according to soil test recommendations. Apply nitrogen according to yield goals, the cost of nitrogen and the value of the animal product being produced on the pasture. The economics of using nitrogen on pastures depends on the utilization of the additional production. This normally requires high stocking rates. For full-season production, apply nitrogen in the spring, the end of June and the middle of August. A light application in early September can build root reserves to help grass pastures overwinter and get off to a faster start the following spring.

pH

The pH is a measurement of the acidity or alkalinity of the soil. Most pasture species are most productive at pHs in the range of 6.0–7.5. A pH below 6.0 is low or acid, while a pH above 7.5 is high or alkaline.

If the pH is too low to successfully grow a desired species, it can be raised by adding lime. Calcitic lime raises the pH and adds calcium to the soil, while dolomitic lime raises the pH and adds both calcium and magnesium to the soil. Liming the soil to raise the pH of acid soils may cause an increase in soil fertility, as phosphorus becomes more available at near-neutral pH and soil microorganisms are more active.

Lime is slow acting in soil. It is best incorporated throughout the root zone; it has limited value when applied to the surface without incorporation. Once applied, lime raises the pH for several years, but with time, the pH gradually falls to the original value.

Alkaline soils with a high pH can limit plant growth, although this is rarely a problem for pasture production. High pH soils may be deficient in micronutrients. In this case, it is more economical to add the micronutrient than to adjust the pH.

IMPACT OF GRAZING ANIMALS ON PASTURE FERTILITY

Most of the nutrients animals eat while on pasture are returned to the ground in either urine or dung. The recycling of nutrients through animals can prove to be either a valuable fertilizer source or the cause of tremendous pasture waste. If not managed correctly, the fouling of pastures can cause selective grazing and a deteriorating pasture.

Urine

Areas in the pasture contaminated with urine are not usually rejected by animals. Sheep actually prefer to graze these areas. Due to the high nitrogen content in urine, plant composition in the affected areas may change. Urine patches receive the equivalent of 300–500 kg nitrogen/ha. This level of nitrogen stimulates grass growth for up to 4 months and may depress legume growth. In hot weather, grasses and legumes may be scorched and killed by urine.

Dung

Animals avoid plants growing near dung. Grasses normally dominate these ungrazed areas, as the nutrients in the manure improves their growth. Depending on the climate, which affects how quickly the dung is broken down, and the stocking rate, the area left ungrazed can be several times larger than the area covered by dung. In fields with low stocking rates, pasture losses because of fouling can be as high as 45%. Under high stocking rates, loss is reduced to 10% or less, as competition among animals for feed forces them to graze closer to the dung. More importantly, the higher density of hooves breaks up and distributes the dung across the pasture.

Dung effects the grazing behaviour of animals long after the apparent disappearance of dung from the pasture. It can take two pasture seasons before a contaminated area is no longer rejected (see Figure 3–1. *The effects of dung on grazing*). Often, the areas between dung patches are overgrazed.

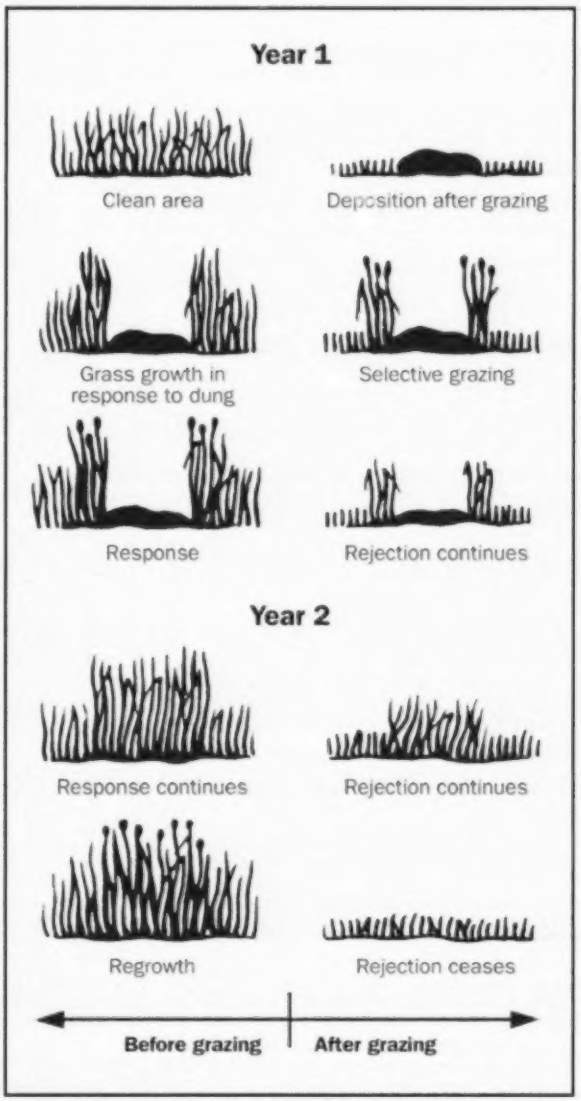


Figure 3–1. The effects of dung on grazing. Animals will avoid grazing areas contaminated with dung for a long period of time.

The pasture underneath dung deteriorates quickly as the plants are either smothered or killed by high nutrient levels. This area is then taken over by nearby plants, or from seeds in the soil or dung. Weeds then establish in a pasture's bare patches. There are extremely high rates of nutrients from urine and dung deposited in the areas where animals camp in the pasture. In time, the "camp" may become bare ground, surrounded by mature grass and weeds.

Regular harrowing with chain harrows or drag harrows pulled upside down spreads the dung, and prevents damage to the pasture and wasted forage. This also uses the natural fertilizer contained in the dung.

Horses foul the same part of the pasture throughout the entire grazing season. Reduce forage wastage by providing a small grazing area at the start of the season. This reduces the area where horses leave their droppings, maximizing the grazing area.

WEED CONTROL

Weed control in pastures starts with selecting forage species adapted to the physical characteristics of the pasture and managing them so they stay vigorous and able to outcompete the weeds. Maintaining 10–25 cm of dense forage growth with a good pasture rotation reduces or eliminates the opportunity for weeds to grow.

To control weeds, determine the state of the desirable plants and the extent of the weed problem. If desirable legumes and grasses are not growing well, assess whether growing conditions or management practices are responsible for their poor growth. Corrections to pH, drainage, fertilizer, grazing management or in the forage species themselves can then be made to develop a thick, competitive pasture.

Certain plant species, called indicator plants, grow in conditions most other plants will not (i.e., wild strawberries indicate low phosphate levels and moss grows on land with very low nitrogen levels).

Weeds indicate a problem.

Management problems usually consist of over- or undergrazing.

Overgrazing occurs when animals graze the forage to the ground. The forage is slow to recover and weeds, with good root reserves, grow faster. The effects of overgrazing are usually seen by midsummer when the pastures have been grazed several times, forage root reserves are low and growth is further slowed by hot, dry weather. Perennial weeds with root reserves that have not been used will grow. Chicory is an example of this type of weed.

Undergrazing allows the forage to overmature and become reproductive. As the forage flowers and sets seed, growth slows and weeds can outgrow the forage. With either over- or undergrazing, changing the rotation to keep the forage between 10–25 cm reduces the opportunity for weed growth.

Types of Pasture Weeds

Recognize the weeds present in the pasture and know their growth habit. Understanding the way a plant grows allows you to control its growth and spread.

Annual Weeds

Annual weeds germinate from seed, grow, flower and set seed during one growing season. Usually they grow quickly in the spring and compete heavily with crops. Since most grow in a disturbed seedbed, they are more of a problem in establishing pastures but are rarely a problem once the pasture is established. Use cover crops or herbicides to control weeds in the first weeks of an establishing pasture. Clip direct-seeded pastures once the forage is established. Most annuals will not regrow after clipping.

Winter annual weeds can be difficult to control in pastures. They germinate in late summer or fall, and grow leaves, usually a rosette, when there is little competition from the pasture. They overwinter as a living plant and resume growing actively as soon as temperatures allow, usually before the pasture starts to grow. Use a chemical herbicide in fall or clip weeds in spring or early summer to prevent seeds from developing.

Biennial and Perennial Weeds

Biennial and perennial weeds cause the most problems in pastures. They grow when pasture species are dormant and non-competitive. Growth of these weeds may be slow the first year or for several years, until the plant establishes root reserves. In following years, the plants send up shoots during periods of low competition from the forage. Plants like dandelions establish a large fleshy storage root to provide energy for early spring growth. Perennials, such as thistles, can also spread by underground stems and roots.

Methods of Weed Control

Most weeds can be removed by clipping. Annuals clipped at flowering are prevented from going to seed and generally will not regrow. Perennials may have to be clipped several times — often over several years. Repeated regrowth and clipping depletes the root reserves of the plants, eventually making them less competitive than the pasture species.

Apply chemical controls at the appropriate growth stage and time of year. Consider:

- the effect of the herbicide on the forage species
- the time you must wait after application before it is safe to graze your pasture

You may need to apply a chemical more than once to kill established perennial weeds. Generally, legumes are damaged by chemical treatments.

Most chemicals are applied in early spring or late fall when the pasture is dormant but weeds are actively growing. Spring application can be difficult if the pasture is wet and there is a possibility of runoff. Fall applications must be made after the pasture is dormant but while the weeds are still actively growing. For a full discussion of weed control, see OMAFRA Publication 75, *Guide to Weed Control*, available at ontario.ca/crops.

Effects of Weed Control

Removing weeds by mechanical or chemical means is a short-term solution. Long-term control relies on removing the problem weed and managing the pasture to prevent re-establishment. Removal of weed species does not necessarily improve yield immediately, as weeds often add to total pasture production. If the majority of a pasture consisted of weeds killed by a herbicide, you must re-seed to prevent other weeds from becoming established on the bare ground. Long-term weed control consists of a combination of grazing management, fertility, chemicals and reseeding, if necessary.

Weeds do not need to be controlled if they are not damaging the pasture. Base your decision to control by determining how much damage they are doing by lowering the yield. If the weed is not lowering overall pasture yield, it may be better to leave it and consider it a forage plant. Dandelions growing in a rough grass pasture may be providing early feed for animals.

Changing your thinking about the weeds is adequate control.

Non-Pasture Areas

Do not limit weed control to the pasture. Fencerows and waste areas are good reservoirs of seed and give perennials an opportunity to grow underground roots out into pasture fields. Clipping these areas once or twice a year keeps most weeds under control. Areas left uncut for natural regrowth or wildlife habitat should be checked for weeds and individual plants controlled.

Weed Control During Pasture Renovation

Weed control during renovation differs from normal weed control. During renovation, young species are poor competitors and susceptible to weed competition. Consider chemical and mechanical weed control until the pasture plants are well established and competitive. Watch your pasture closely to ensure weeds do not outcompete the pasture species. Alternately, you could use animals to keep all existing plants grazed down, allowing the new species to establish.

Poisonous Weeds

Not all plants are benign. Some are poisonous to animals. The toxicity of plants varies with the amount of plant ingested, growing conditions and animal health. Symptoms of poisoning include restlessness, loss of appetite, chills, tremors, etc. See the OMAFRA Factsheet *Poisoning of Livestock by Plants* for a description of these weeds, where they are generally located and the symptoms of poisoning.

If you see any indication of poisoning, consult a veterinarian.

Poisonous plants are normally eaten when pasture conditions are poor and there is little else for animals to eat. Take special care if animals have access to wooded or swampy areas, where poisonous plants grow without competition.

Not all poisonous weeds have to be eaten to harm animals — some cause dermatitis. Watch fencerows and waste areas. Horse owners should watch trails and riding areas for plants that cause rashes, inflammation and animal discomfort.

Control all poisonous plants near animals.

TRAMPLING EFFECTS

Livestock affect a pasture and its productivity in more ways than by just grazing. Animals walking or running across a pasture can cause damage. Trampling physically injures plants. It is easy to see the full effects of the damage on frequently travelled paths, near watering spots, mineral feeders or gateways. Some plant species such as alfalfa, red clover and timothy are very susceptible to this type of damage, while bluegrasses, creeping red fescue, tall fescue, perennial ryegrass and white clovers are fairly resistant. The differences in tolerance to trampling can produce changes in the plant make-up of the pasture. The susceptible species die out and are replaced by the resistant species or new plants that germinate from seed in the ground. High stocking rates can depress yields because of trampling damage (see Table 3–4. *Summer Dry Matter Yields Affected by Trampling Damage*).

Trampling damages pastures by causing soil compaction and puddling — where air or water-filled pore spaces are replaced in the soil, restricting oxygen to plant's roots. Trampling depresses fertilizer and water movement in the soil, reduces nitrogen fixation and impedes root growth. Plants on compacted soils develop more roots at shallower depths and become susceptible to dry weather. This type of trampling damage occurs when pastures on silt, clay or soils with a high organic matter are grazed during wet conditions. Damage escalates as the size and number of animals grazing the pasture increases.

Table 3–4. Summer Dry Matter Yields Affected by Trampling Damage

Sheep /ha	Perennial Ryegrass	Orchardgrass	Other grasses
0	840 plants/m^2	110 plants/m^2	270 plants/m^2
40	800 plants/m^2	40 plants/m^2	120 plants/m^2
80	760 plants/m^2	30 plants/m^2	120 plants/m^2

Source: Edmond, D. *The Influence of Animal Treading on Pasture Growth.* Proceedings of the Xth International Congress, Helsinki, Finland, pp. 453–458.

To keep trampling damage at a minimum, follow these management practices:

- Use rotational grazing to encourage the development of a dense, healthy pasture.
- Use tolerant grasses and legumes on fields prone to trampling damage or for heavy traffic areas.
- Improve field drainage where practical.
- Ensure a good level of soil fertility.
- Use one area as much as possible for grazing during wet periods. This limits the area exposed to trampling damage.

Much of the damage to soil from trampling is repaired by frost action and the activity of worms and other life forms in soil. If these are unable to overcome soil compaction and puddling, consider mechanically slitting the soil.

High stocking rates can lower yields because of trampling damage.

4. Grazing Management

ANIMALS AS GRAZERS

Animals affect pastures and pasture productivity by trampling, spreading seeds, recycling nutrients and by grazing.

Grazing management has the largest effect on pasture productivity and survival.

Animals generally graze 7–12 hr a day, and within a livestock class, this stays the same, day to day. The peak periods of grazing are after daybreak, in the late afternoon and around midnight. When the weather is hot, animals spend more time grazing at night. The amount they eat daily depends on their bite size and the rate at which they eat. When forage supply and quality is good, they take fewer, larger bites than when forage is in short supply. When the grazing is good, cattle and sheep take approximately 36,000 bites a day.

Bite size is the key to high intakes that result in improved animal performance. To have high-quality forage in abundant quantity for animals to graze, it is necessary to provide adequate time for the grazed grass to recover from the previous grazing.

Rest and recovery are the keys to productive pastures.

Animals maintain their feed intake as the pasture gets shorter by increasing the number of bites per minute and by grazing longer. However, a point is quickly reached when animals cannot eat enough small mouthfuls of forage in a day to meet their nutritional needs.

When forage supply is plentiful, animals select the highest-quality forage present. They prefer leaves over stems, and try to avoid eating dead plant material, trampled plants contaminated with soil and plants growing near dung. Different animals prefer different plant species, or a different proportion of those plant species, in their diet.

Animals use sight, smell, texture and taste to choose the plants to eat and, if given the chance, eat only what they like. This can result in spot grazing. Plants in the grazed areas are kept in a short, immature, leafy condition and have a high feed quality. Usually there is not enough quantity in these overgrazed areas to satisfy the nutritional requirements of the animals, and the plants eventually die from being overgrazed.

Plants that are not grazed become mature, are less attractive to the animals and are wasted. With time, the less attractive plants become the dominant plant species in the pasture. As the forage supply per animal decreases, the degree of selectivity decreases. Ideally, stocking rates should be high enough to eliminate most, but not all, of the selective grazing. Animals perform better when there is some opportunity for selective grazing.

Animals have different abilities to be selective grazers. Sheep and goats are the most selective, followed by horses and then cattle. The ability of animals to be selective grazers and to graze plants at different heights depends on their mouth parts. How the grazing is managed will have a large impact on both animal performance and forage growth.

Cattle

Cattle use their tongues to pull plants into their mouths. This means they are unable to graze as selectively as sheep, goats or horses. They are also less able to maintain feed intake when grazing short plants. Graze cattle in pastures 10–30 cm tall.

The ideal height ranges from 10–30 cm. At this range, mature animals graze at a rate of 70–80 bites per minute and eat 70 kg of forage a day. Cattle eat at this quick pace because they easily form a food bolus, swallowing the feed without lifting their heads. When pasture plants are tall (30 cm), cattle have difficulty forming a food bolus. They must lift their heads up to form the bolus and swallow. This reduces the number of bites they take per minute, reducing feed intake to 30–40 kg/day. When grazing short plants, less than 8 cm tall, cattle eat only 15–20 kg of forage/day. Cattle grazing plants shorter than 10 cm cannot get enough energy or protein to meet their daily requirements.

Cattle prefer to graze fine grasses over broad-leaved grasses or legumes. They like to change the area they graze frequently; therefore, rotational or strip grazing suits cattle. Do not keep milking dairy cows longer than 2 days in the same paddock. Ideally, give milking cows fresh pasture at least once a day and preferably after each milking. At no time should animals be more than 5 days in a paddock. Plants start to regrow in about 5 days, and this new growth, which is all from root reserves, will be consumed, weakening the plants. If animals are left longer than the third day in a paddock, they are forced to graze "left-overs" from the previous day's grazing, and intake declines, resulting in reduced performance. Top-producing pastures can support two milking cows per hectare for the grazing season. Dairy heifers and dry cows do not have to move as frequently as the milking herd and can stay a maximum of 5 days in a paddock or field. Beef cattle benefit from being moved every 3–4 days; do not leave them longer than 5 days in a paddock or field.

Sheep

The structure of sheep lips and the way they use their tongues allow sheep to be very selective grazers. They can easily choose one leaf over another from the same plant. They prefer to graze plants in the following order: forages, broad-leaved grasses, fine-leaved grasses, sedges and dwarf shrubs. Their relatively mobile upper lip allows them to graze pastures closely, making them much better at maintaining forage intake on short pastures than cattle.

However, in order to perform well, ewes need at least 550 kg of dry matter/ha available for grazing at all times. Lamb production is very sensitive to forage availability and quality, as they have high nutrient requirements. Finishing lambs needs 1,000 kg of dry matter/ha. Sheep pastures should be no lower than 6 cm in height when the sheep are removed from the field. Grazing shorter will result in slower forage recovery. A residual height of 7–10 cm is preferred for optimum forage growth. If the pasture is thin, increase this minimum height.

Goats

Goats are similar to sheep in their ability to selectively graze but prefer a wider range of plants in their diet. They are quite adaptable and browse more easily than sheep or cattle. Up to 80% of their diet can be from small trees and shrubs. Graze milking goats, with their high protein and energy requirements, on pastures with high-quality forage.

Horses

Horses are selective grazers and can bite plants off closer to the ground than cattle. They tend to be spot grazers, grazing one area close to the ground and leaving other areas for droppings. Under low stocking rates, the field develops a pattern of heavily and lightly grazed areas. They spend a longer time grazing than ruminants. A mature horse needs up to a hectare of productive pasture for the entire grazing season; heavy horses require an additional hectare. Horses need space to run. Keep this in mind when designing paddocks. They need relatively large areas, and long rectangular paddocks are preferable to small, square paddocks.

EFFECTS OF GRAZING ON PLANTS

Plants use water and carbon dioxide in the presence of sunlight to create carbohydrates and oxygen (a process called photosynthesis). Plants use carbohydrates as an energy source for growth. When plant growth slows and more carbohydrates are produced than needed for growth, the surplus carbohydrates are stored. These reserves are important for the plant's survival over winter and for initiation of plant growth in spring. Regrowth after grazing depends on energy being produced either by the remaining leaf area or from the carbohydrate reserves.

The aim of grazing management is to:

- harvest the plants while leaving enough top growth and root reserves to support fast regrowth
- allow the plants adequate time to recover from being grazed

Plant growth starts slowly in the spring or after close grazing. Carbohydrate reserves stored in stem bases, roots, rhizomes and stolons have to be mobilized before they can be used to fuel growth. In grasses, the dependence on reserves for regrowth usually lasts 2–7 days, while in legumes, it can be 2–3 weeks. Once leaf area develops, growth quickens as the plant has an immediate source of energy from photosynthesis. After this vegetative period of fast growth is over, the plant becomes reproductive, growth slows and carbohydrate reserves are replenished. Grazed plants left with enough leaf area to continue photosynthesizing regrow at a quicker rate, as they are not dependent on carbohydrate reserves.

Frequent close grazing of plants can be damaging because the plants are unable to restore their carbohydrate reserves. With each defoliation, the plant's reserves are reduced and, with time, depleted. In addition, any intensity of grazing causes plant root damage, reducing root weight, length and vigour. The extent of the damage increases with the severity of the defoliation. Loss of roots slows plant growth as the plant cannot obtain sufficient water or minerals to support rapid growth. Severe overgrazing removes so much of the leaves that there is insufficient energy produced to keep the roots alive, and the plant is unable to survive.

An important part of grazing management is to allow plants adequate time to recover from being grazed. The amount of time needed for this changes during the pasture season. Plants grow at different rates during the grazing season due to changes in growing conditions.

When grasses are grazed — that is, at what stage of growth — influences how well they survive and regrow. Grasses are made up of individual tillers, each having a growing point (that controls the growth of the tiller and may form a seed head), a stem, leaves, roots and dormant buds. In the vegetative growth stage, the growing points are close to the ground — safe from being eaten — and produce new leaves after being grazed. Growing points continue to produce new leaves until the plant goes into the reproductive stage or until the growing point is elevated by stem elongation.

With grasses such as Kentucky bluegrass, tall fescue and orchardgrass, stem elongation occurs as the plant goes into the reproductive phase. Forage production from these grasses is encouraged by frequent grazing. Grasses such as timothy, bromegrass and reed canarygrass elevate their growing point early in their growth and regrow slowly if grazed too early (before the boot stage). New growth must come from the dormant buds, and the energy for that growth must come from the remaining leaf area or from reserve carbohydrates. These grasses are suited for controlled grazing, where they can be harvested quickly and given a rest period in which to recover and regrow.

GRAZING MANAGEMENT SYSTEMS

Grazing management should:

- balance livestock demand with forage availability
- promote rapid pasture regrowth during the grazing season
- promote long-term pasture persistence

The goal of grazing management is to ensure that there is sufficient pasture in a stage suitable to graze at all times throughout the grazing season. Several grazing management systems define different methods of harvesting the forage.

Continuous Grazing

Continuous grazing means putting a set number of animals out on a pasture and leaving them there for as much of the season as the pasture will support them. The number of animals the pasture can support is determined by the forage yield during the period of poorest pasture productivity, usually July and August. In most cases, the stocking rate needs to be very low or the animals will lose weight during the summer. Individual animals can milk or gain well under this type of grazing management if stocking rates are low enough.

Drawbacks to Continuous Grazing

The drawbacks to this type of grazing management are:

- meat or milk production per hectare is very low
- most of the forage produced in the spring is wasted
- the animals selectively graze and cause the pasture to become less productive with time

Managed grazing will result in improved productivity of the pastures and of the livestock grazing the pastures. There are a number of different approaches to managed grazing, each with its advantages and disadvantages. Each of the systems requires more day-to-day management but will pay significant dividends to the pasture manager.

Advantages of Managed Grazing

The advantages of managed grazing are:

- more of the produced forage is used
- higher numbers of animals can be supported by the pasture
- more meat or milk is produced per unit of land
- the pasture recovers quickly after being grazed and remains productive for a longer period of time
- taking a hay or silage cut is possible if there is an excess of forage in the spring
- desirable legumes and grasses are able to persist from year to year

Rotational Grazing or Management-Intensive Grazing

Rotational grazing involves fencing a pasture into a number of small paddocks — a minimum of 10–12 and preferably 30 or more. Subdivision is a useful way to balance livestock needs with forage supply. Livestock graze the paddocks in sequence, moving to a new paddock when the forage is ready for grazing. In general, put livestock into a paddock when the forage is 25–30 cm tall; remove livestock when the pasture is grazed down to 8 cm. A relatively high stocking density for the size of the paddock forces the animals to be less selective in their grazing and to graze the paddock off evenly. The animals are removed before they start to graze new plant growth, and the paddocks are rested.

Dividing the fields may allow some of the paddocks to be harvested for hay early in the season. This hay can be fed back if and when the pastures do not produce enough forage for the livestock. When planning the area to be cut, consider how much will be needed to support the livestock until the hay aftermath is ready to be grazed. The later the first cut, the slower the regrowth. This delays putting the cut area back into pasture rotation and puts extra pressure on the grazed area.

Rotational grazing does not necessarily increase daily liveweight gains but does allow a heavier stocking rate to be carried, which increases gains per hectare. It has been observed that a well-managed rotational grazing system will provide 4–6 weeks more grazing then a continuous grazed system. This is especially evident from mid-July to early September.

Strip Grazing

In this system, the animals are given just enough pasture to supply half to one-day's requirements. The fence is moved once or twice daily to provide fresh forage. A second wire can "follow" the animals to prevent movement back onto grazed areas. While this is the most labour-intensive method of grazing, it results in the highest-quality feed, the least waste and least damage to a pasture.

Forward Grazing

This is a variation of rotational grazing where the pasture is grazed by two groups of animals.

The first group into a paddock are those with the higher nutritional needs. They graze the tops of the plants — the most nutritional — and are not forced to graze forage of lower quality. The second group, with lower nutrient requirements, graze the forage left by the first group. This system works well where milking cows are the first to graze a paddock, with dry cows or heifers used to clean up the pasture.

With beef cattle, calves are allowed access to pastures ahead of their dams. This system provides higher weaning weights when forage is limited or where competition between young stock and dams exists. It is easy to establish, using creep gates or installing a division fence high enough in mid-to-late summer to allow young animals to be first grazers.

Mob Grazing

This is a form of rotational grazing in which large numbers of animals graze the paddocks for a short period of time (hours). The animals are left in a paddock until all the forage is grazed down or tramped into the soil. This method is particularly good at rejuvenating an overgrown, worn-out pasture. Stock densities of 20–75 kg of animal/m^2 are generally used (200,000–750,000 kg of animal/ha). This approach is normally used to clean up pastures with a lot of coarse, mature plants. Mob grazing can replace clipping.

Twice-Over Grazing

In twice-over grazing, the pasture is split into four or more sections, and each section is grazed twice during the year. The first time through, at the beginning of the grazing season, the livestock spend 1–2 weeks in each of the paddocks. On the second time around, the stay is lengthened to 3–4 weeks' stay in each paddock. This approach is less intensive but still lets the pastures rest and re-grow about 75% of the grazing season. This approach is particularly applicable to less-productive large-acre pastures.

Mixed Grazing

This approach to grazing management takes advantage of the fact that different types of livestock like to graze different plants. Two or more types of animals graze the paddock at the same time or follow one another through the paddocks. Sheep and cattle make a good combination. Do not graze sheep with horses.

DESIGNING A ROTATIONAL GRAZING SYSTEM

To design a rotational grazing system, take an inventory of:

- the state of your pastures
- the layout of current fences
- the location of watering and handling facilities

To keep costs reasonable, incorporate the existing fencing into the scheme. All paddocks must have access to water, and the layout must accommodate this. An alley system is useful for moving livestock back and forth to a common destination (see Figure 4–1. *Diagram of an alley system*).

Figure 4–1. Diagram of an alley system. In a field divided for rotational grazing, an alleyway allows access to water and handling facilities from all paddocks.

Estimate the productivity of the pastures. Paddocks do not have to be the same size, but it is easier to manage them if they have a similar degree of productivity. Divide extremely productive pastures into smaller areas than poorly producing pastures. Set up paddocks on hills to run across the field, rather than up and down. This eliminates the selective grazing that normally takes place on slopes. If given the opportunity, livestock will camp on the top of hills and reject the forage at the bottom.

Number of Paddocks

The number of paddocks required is based on the length of time it takes for the pasture to recover after being grazed. This is essential for keeping the pastures productive. A French scientist, André Voisin, devised the following simple formula to calculate the number of paddocks required for efficient grazing:

Days of rest required ÷ Days of grazing in one paddock + 1 = Number of paddocks required

Length of Rest Period

The number of days required for rest differs over the grazing season. In the spring cool season, forages grow at twice the rate than in summer. A good working guideline is that it takes approximately 20 days in the spring and 30–45+ days in the summer for most forage species to recover after grazing. However, the recovery rate is influenced by the individual species, how they have been grazed and the weather. The required rest period fluctuates not only within the season but also from year to year. A good rotational system must be flexible to handle these changes.

Days of Grazing per Paddock

The time the animals spend in a paddock must be long enough to graze the pasture off evenly but short enough to prevent grazing of new regrowth. The faster the animals are in and out of a pasture, the better, in terms of forage production (see Table 4–1, *Dry Matter Yields as Affected by Length of Grazing Period*).

Five days is the maximum time that animals should remain in a paddock. The animals should be moved on to the next paddock when it is ready to be grazed even if they have not finished grazing the first. In a multiple paddock system, look at the last paddock in the system to determine when to move. Estimate when the last paddock will be at optimum grazing height and adjust the rotation speed so the animals arrive when that paddock will be optimum. This is to prevent the next field from becoming too mature and being largely wasted by the animals. If the animals cannot keep up to forage production, take a hay or silage crop, if possible.

Shorter grazing periods encourage higher pasture yields.

Table 4–1. Dry Matter Yields as Affected by Length of Grazing Period

Mixture	Time in Paddock	Dry Matter Yields (kg/ha) by Month				
		May	June	July	Aug	Total
Alfalfa + ladino + brome + orchard	1 day	1,880	2,210	1,870	1,960	**7,920**
	7 days	2,190	1,420	1,690	1,630	**6,930**
Ladino + orchard	1 day	1,770	2,260	1,570	1,710	**7,310**
	7 days	2,040	1,340	1,280	1,290	**5,950**
Trefoil + timothy	1 day	690	2,180	1,340	1,370	**5,580**
	7 days	940	1,380	1,200	970	**4,490**

Source: R.S. Fulkerson. Ontario Agricultural College, University of Guelph.

Because of the differences in recovery rates in the spring and summer, fewer paddocks will be required for the spring period than in the summer. By using a quicker rotation in the spring and getting to all paddocks in a timely manner, you should be able to keep the paddocks in a vegetative state. If the growth gets too far advanced, consider making hay or silage on a few paddocks. The other option is to expand the land base for summer grazing by incorporating the aftermath of hay fields. The goal of the pasture manager is to have a supply of quality pasture available throughout the grazing season. Rotating through a number of paddocks will allow you to maintain a supply of quality forage at all times. In years with very dry summers, it may be necessary to reduce the stocking rate, add some hay fields to the rotation or use supplemental feed if there is not sufficient pasture available from the dedicated pastures.

Paddock Shape

Other than for horses, paddocks work best if they are square, rather than rectangular or irregularly shaped. Long, thin paddocks tend to encourage livestock to graze at the end nearest water, minerals or shade, and to avoid grazing the distant end. Square corners are easier to hay or clip. Design your paddocks to allow access to machinery for carrying out these operations as well as fertilizing.

Throughout the grazing season and at the end, evaluate the performance of your pastures. If some of the paddocks are regularly not grazed off evenly, then subdivide that specific paddock to encourage better grazing next season.

STOCKING RATE

The success of using rotational grazing management depends on having enough animals to graze the small areas quickly. The number of animals this takes depends on the pasture, the complexity of the rotation and the growing season. Too high a stocking rate leads to competition between the animals for forage, lowering weight gains or milk yields. A low stocking rate gives top animal performance but poor gains or milk yield per area of pasture. The ideal stocking rate strikes a balance between individual animal productivity and production per hectare.

Productive pastures can support two animal units per hectare for the grazing season. By planning to carry one animal unit per hectare in the summer, a safety factor is built into the system in case of drought (see Table 4–2. *Animals per Livestock Unit*).

Estimate the stocking rate of your pasture:

- Estimate animal consumption on a daily basis.
  - Grazing animals require about 2%–5% of their body weight per day (lactating dairy cows need 3%).
  - Average animal weight x .025 = forage dry matter needed by one animal each day.

Estimate the forage available for grazing per cycle:

- Use visual assessment. By walking across the pasture, you will develop an eye for how much forage is there.
- Check pasture height. This gives an indication of dry matter yield and herbage intake. A ruler or meter stick can be used.
- Use rising plate meters.
- Employ electronic probes.
- Estimate from hay yields.

Calculate stocking rates (animal/unit area):

- Calculate from the longest cycle in the season to determine the maximum number of animals that can be carried. This cycle is 40 days long.
  - Forage availability per day per cycle (FADC) = forage availability ÷ 40.
  - Stocking rate = FADC ÷ estimated animal consumption

Table 4–2. Animals per Livestock Unit

Type of Animal	Ideal Number
Milking cow	0.7
Beef cow with or without calf	1
Feeders, replacement heifers	3
Horse	1
Mature sheep, goats	8
Feeder lambs, kids	20

Source: Nutrient Management Act.

INTRODUCING LIVESTOCK TO PASTURE

A gradual conversion to pasture is best.

- **Start early.** Spring pasture growth is quick. Animals can go on pasture when the forage is greater than 7 cm tall, provided the fields are dry enough to support the animals and the animals are going to be removed when the forage is 5 cm tall. If possible, wait until there are two leaves on the grass plants. Do not graze too short, your first rotation is setting the stage for the rest of the year. If you set the plants back in the spring, they will not be as productive for the rest of the grazing season.
- Practice bloat control management if pastures have a high content of bloat-causing legumes.
- **Start cows at 2–3 hr of grazing per day.** Gradually increase the time on pasture. This will help the animals adapt to grazing and the rumen microbe population adapt to the fresh pasture forage.
- **Take 2–3 weeks** to make the conversion if the pasture is supplying all or most of the forage component of the diet.
- Adjust rations fed in the barn by gradually feeding less stored forage as the cattle transition to a full pasture forage diet.

CLIPPING PADDOCKS

Mow coarse plants around dung areas or accumulated on under-utilized areas. Mature forage is low in feed quality and less palatable than vegetative forage. Clipping stimulates new growth and prevents animal rejection in future grazing periods. If the plants are clipped early enough, the livestock will eat the clippings. Clipping also helps control weeds. A well-managed pasture should not require more than one clipping per season.

Nutritional Supplement for Dairy

For dairy cows milking over 27 kg of milk per day, consider the following:

Factors and Considerations

Grain/Carbohydrate:

- The type of grain or carbohydrate doesn't significantly affect milk production but can affect milk composition.
- Cereal grains reduce milk fat more than corn or feed by-products such as soy hulls or corn gluten feed.
- Grains increase milk protein more than fibrous concentrates.
- Feeding fat to grazing cows as an energy source doesn't significantly increase milk production but may improve body condition and reproductive performance.
- The only opportunity to feed grain to cows on pasture may come twice daily at milking.
- Large amounts of grain (slugs) can disrupt rumen function. Feed with supplemental forage to buffer rumen pH.

Amount Fed:

- Feed grain at a rate of 1 kg per 4–5 kg of milk while pasture is good.
- Feed at rate of 1:3 in midsummer to late fall.
- As supplement feed increases, amount of pasture eaten decreases.

Pasture Quality:

- Cows grazing poor pastures require much more energy than cows grazing high-quality pasture.
- High-quality pastures are high in crude protein (CP), but low in undegradable or bypass protein.
- Highly degradable protein is converted to urea, which is usually excreted in urine.
- Feeding grain improves nitrogen utilization in rumen, thereby decreasing urea excretion in urine and improving milk production.
- Large amounts of supplemental CP aren't needed if pasture quality is good. A concentrate that contains 10%–14% CP is adequate.
- Grain feeding during periods of slow pasture growth or to cattle grazing poor pastures can reduce the need for supplemental forages.

Supplemental Forage:

- Providing stored forage (hay or haylage) doesn't improve milk production or quality when pasture supply and quality are good.
- If feeding supplemental forage, limit feed forage to 1.5–2.5 kg per cow per day.
- Increase supplemental forage if pasture production drops or to help correct milk fat depression.
- Limited feeding of stored forage will:
  - detect off-feed cows
  - prevent bloat on high-legume pasture
  - improve fat test (in some cases)
  - improve rumen stability and health
  - enable removal of cows from pasture at least 2 hr before milking on milk-tainting pasture, e.g., annual rye, brassicas, some alfalfas
  - enable confinement during very hot, humid weather
  - reduce looseness in manure
  - ease transition between stored feed programs and pasture

Pasture Supplements

Free-choice supplements are designed for use on pasture. They are an easy method of supplying nutrients and/or additives to livestock.

Type of Pasture Supplement and Function

Mineral and Vitamin:

- general purpose
- for use with high-quality pastures

Protein, Energy:

- protein from any combination of animal, vegetable, protein and urea
- energy usually based on molasses, but may include fat
- for use with medium-quality forages
- also contain vitamins and minerals

Specialty Supplements

- products formulated to meet specific requirements of animals at various stage of production

Tips

- Ensure supplement suits intended use.
- Follow label directions to ensure correct levels of supplement are being consumed by each animal.
- Be aware of general feeding recommendations:
  - Ensure animals aren't "salt hungry" when first introduced to pasture supplements. Feed salt and a mineral-free choice for at least 7–10 days prior to introducing pasture supplement.
  - Ensure animals aren't hungry when first introduced to a supplement.
- Don't let animals run out of supplement once it has been introduced. If it does run out, reintroduce it carefully.
- Provide free access to fresh water.
- Follow any cautions concerning pasture quality and quantity.

5. Fencing Management

Fencing is the key to pasture management. It allows a livestock producer to rotate pastures and control livestock and predators. Many types of fence are used in Ontario to provide a physical barrier. They include an assortment of cedar rail, stone, page wire, barb wire, suspension, high tensile and board fences.

Livestock farms need at least an exterior or perimeter fence. Interior fences allow a farm to be subdivided, and moveable fences add flexibility to grazing management. Electric fencing offers this versatility and is effective and inexpensive.

ELECTRIC FENCING

Electric fencing can replace worn-out fences or be used as a new fence. It will support and extend the life of a page wire or rail fence (see Figure 5–1. *One-strand high-tensile wire supporting a rail fence*). The high cost and labour involved in putting up and maintaining traditional fences has made electric fencing more attractive. When properly constructed, modern electric fencing is much more dependable than the older style battery-operated units used in the past.

Training

Electric fencing is a psychological, rather than a physical barrier. The success of electric fencing depends on training your livestock to respect the fence. Try the following:

- keep your training area small
- place a charged wire inside a permanent corral or barnyard fence, where there is little chance for escape
- leave your livestock inside this area for a few days to familiarize themselves with this electric fencing before putting them out to pasture

Untrained, an animal may try to go through the fence. But many hours of time can be saved rounding up livestock and repairing fences if the animals are well trained.

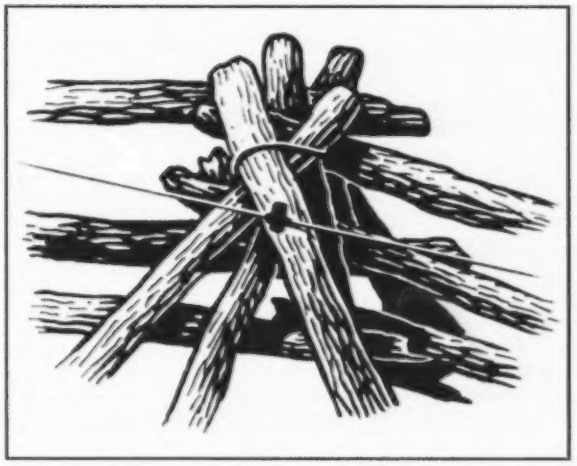


Figure 5–1. One-strand high tensile wire supported by a rail fence.

How Does It Work?

A power source, either hydro or battery operated, is needed to operate the energizer. The energizer sends out a current in a pulse. Wire is used to carry the current along the fence. A ground completes the circuit. When an animal comes in contact with a live wire, it shorts the current to the ground and the animal receives a shock.

An electric fence line with no vegetation touching it requires very little power to maintain high voltage levels. Normally, the fence will have to handle some plant growth. This is called the "fence load." Every plant in contact with a live wire draws a small amount of current to the ground. With miles of wire, this power drain can reduce your fence's effectiveness.

ENERGIZERS

There are many energizers (also called chargers or controllers) on the market. The type needed depends on:

- the distance you are fencing
- the number of electrified wires
- the amount of vegetation on the fence line

The available power source and power requirements determine whether a hydro, battery or solar unit is best. Hydro (alternating current) units are most effective and require less maintenance.

Energizers are often rated in miles of wire. A 16-km (10-mile) unit will power 16 km (10 miles) of single strand fence or 8 km (5 miles) of double strand fence under no-load conditions. Most fences run through bush and long grass. Under heavy-load conditions, a unit rated for 16 km (10 miles) may be sufficient for 3 km (2 miles) or less. Output joules more accurately estimates ability to carry current for a long distance. One joule for every 10 km (6 miles) of electrified wire is a guideline.

Compare energizers based on cost per joule. The current that travels on the wire is measured in volts. Minimum voltage recommended for cattle is 2,000 volts, 2,500 volts for sheep and 1,500 volts for horses. Higher voltage will provide stronger reinforcement to the livestock that the fence is to be respected. All units need lightning protection against power surges on the hydro line and to be kept under cover from the weather.

Consider future needs when buying an energizer. Purchasing a unit larger than presently required may save buying another one later. Solid state circuitry and modular service boards make repairs easier. Check the guarantee.

Grounding Electric Fences

It is extremely important to properly ground electric fences by attaching the ground terminal of the energizer to a ground rod or rods. This allows the current to make a full circle through the live wire to earth to the ground rod and back to the energizer (see Figure 5–2. *Grounded electric fence*). Galvanized steel rods 12 mm (½ in.) in diameter or 19 mm (¾-in.) galvanized pipe work well. Where soil type allows, make your ground rod 2 m (6 ft) or more. If more than 1 rod is needed, place them at least 3 m (10 ft) apart in a triangle pattern. Connect rods with 12.5-gauge wire. Grounding is the key to an electric fence system. Follow the owner's manual instructions on number and length of ground rods.

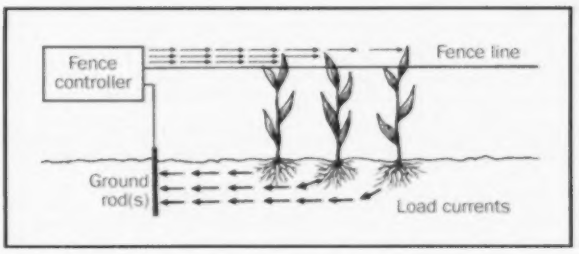


Figure 5–2. Grounded electric fence. An electric impulse travels from the energizer along the wire to plant or animal to ground, to ground rods and back to ground post on energizer.

For best results, place the rods into damp earth. Keep the energizer ground 23–30 m (75–100 ft) from a hydro ground and lightning diverter ground. Use a heavy gauge wire, at least 12.5 gauge, from the ground rod to the energizer. Make sure all connections are clean and free of rust. Use the same type of metal wire to avoid corroding. Clamps should be tight. **Most electric fence problems are a result of a poor ground.**

Under dry conditions, run one fence wire as a ground wire separated from a live wire by 13 mm (1/2 in.). This ground wire is connected to the ground post on the energizer. When an animal touches both a hot wire and a ground wire, it completes the circuit. In this way, the soil is not used to complete the circuit back to the energizer. This gives the maximum shock.

Testing for Sufficient Grounding

To test for sufficient grounding, operate the energizer and short out the fence by laying a number of steel rods (or T-posts) on the wires at least 91 m (300 ft) away from the energizer. The voltmeter connected to a live wire should show less than 1,000 volts. Take a reading between the grounding rod and the soil at least 1.2 m (4 ft) away from the rod. The voltmeter should read less than 400 volts. If a voltmeter is not available, touch the ground rod with one hand and the soil with the other. You should not feel a current if the fence is operating properly. If there is a problem, it is because more ground rods are needed, ground rods are too close or there are poor connections between wires and ground rods.

Wire

An energizer is only as good as the wire. Current on a fence can be compared to water in a pipe. The larger the pipe, the more water it can carry. Larger wire has less resistance to the current. A 12.5-gauge wire has about one-third the resistance of a 16-gauge wire. This means it will carry the current a greater distance under similar conditions. The lead-out wire from the energizer should be at least 12.5-gauge.

For permanent fences, a high-tensile wire lasts the longest. It withstands fallen trees or branches. Polywire, polytape, 14-gauge wire and 16-gauge wire are suitable for temporary fencing. This wire can be rolled up and moved with little effort, especially if insulated hand reels are used. Polywire and polytape are recommended for short stretches of fence. Both have high current resistance. Polytape is quite visible and recommended for horses.

A Spinning Jenny is very useful when stretching high-tensile wire. It allows the roll of wire to feed out smoothly and avoids tangling. Wire tighteners help control wire tension. An electric fence does not require a lot of tension unless it is acting as a suspension-type fence as well.

Number of Wires

Depending on the type of livestock, use at least two high-tensile, 12.5-gauge wires on permanent fences. One wire supports the existing rail or page wire fence, with the use of stand-off brackets. One or two wires are adequate for cross fencing.

Wire Spacing

One strand of wire 76 cm (30 in.) from the soil controls cows, yearling heifers and horses. Two strands at 46 cm (18 in.) and 91 cm (36 in.) from the soil are often used for cows with calves, young heifers and horses with foals. For sheep and goats, a 3-strand fence at 23 cm (9 in.), 46 cm (18 in.) and 76 cm (30 in.) above the ground is effective.

POSTS

Choice includes cedar, plastic, steel stakes, fibreglass and trees. Steel stakes will ground the fence if an insulator is cracked. With trees, leave the nails loose to prevent the tree growing around the insulator. This can result in plastic and nails lodged in trees. The type of post you use depends on whether the fence is permanent or temporary, the type and number of wires, the distance between posts and the cost.

A permanent fence with two or more high-tensile wires requires strong braces. This is the last line of defence. However, posts are needed just to hold up the wires.

A temporary fence should be easy to set up and take down. Plastic, steel or fibreglass posts are all suitable for temporary fence and provide for good flexibility, although more expensive tumblewheel systems are convenient and work well where frequent moves to fresh pasture are being made.

The distance between posts will vary with the lay of the land. Posts can be placed apart 30 m (100 ft) or more on level land — the further apart, the stronger the post needed to carry the weight. A cedar post with a 13- or 15-cm (5- or 6-in.) top is satisfactory. Spacers are placed between posts to keep wires equal distance apart. On rolling land, posts are closer to enable the fence to follow the hills and valleys. Place posts at right angles to the ground surface on slopes, where possible, to maintain the fence height.

Brace Posts

With a high-tensile, smooth wire fence, the wire load is directly on the brace posts. The wires are suspended on posts by the insulators and move freely. This means the brace posts must take the brunt of any force on the wire and the weight of the wires. Keep in mind that stronger braces are required where a suspension effect is desired.

Tests done by Alberta Agriculture show that two brace designs proved the strongest of those tested. The 3-m (10-ft) diagonal end brace and the 3-m (10-ft) single span horizontal end brace are the strongest (see Figure 5–3. *Diagonal end brace and single-span horizontal end brace*).

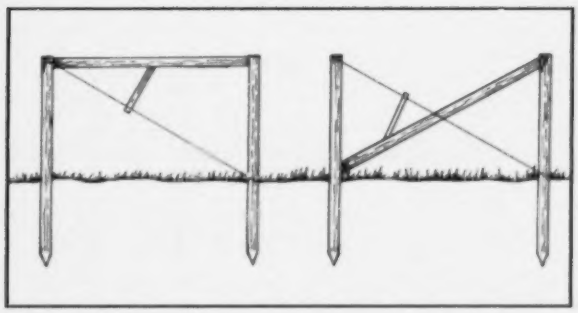


Figure 5–3. Diagonal end brace and single-span horizontal end brace.

The double-span end brace was given a lower rating because of the extra difficulty and expense of construction. All three posts must be directly in line to be effective.

Soil type has a bearing on the effectiveness of an end brace. Friction between the soil and the post is the key. Heavy clay provides a lot of friction, while sandy soil has less. Larger end posts are advisable in sandy soil.

Insulators

Except for self-insulating posts like plastic or fibreglass, insulators are necessary. Insulators hold the wire to the post and prevent it from shorting out.

Insulators are usually porcelain or plastic. Porcelain will last longer but breaks more easily. Nylon, polyethylene and fibreglass are also available. Insulators with protection from ultraviolet rays will last longer.

Wire should move freely through the post insulator. This allows the entire fence to absorb the force of a fallen tree or charging animal.

GATES

Gates may consist of a wire spring or polytape with a handle. The gate must be visible and control livestock, particularly on a perimeter fence. A hot wire is often run through insulated cable underneath the gate opening. This leaves the fence charged if the gate is open.

LOCAL REGULATIONS

A number of municipalities have bylaws on the use of electric fencing. Check at your local municipal office to avoid surprises.

PROTECTION FROM LIGHTNING

Clouds build high charges (millions of volts) during a thunderstorm. These charges are neutralized by arcing to another cloud or to the ground.

An energizer can be struck by lightning in three different ways:

- Lightning can make a direct hit on the electric fence. The longer the fence, the more likely a strike.
- Lightning may strike a building or tree near the fence, inducing very high voltages along the wire.
- The power line serving the farm may be struck, sending a surge through the power cord to the energizer.

Well-constructed energizers have built-in protection against power line surges and strikes near the fence line. This type of unit is effective if properly grounded. The energizer, however, has no protection against a direct hit on the fence line. For a farm with a very long fence or in a lightning-prone area, consider one of the external protection systems outlined below.

- Choose a position 91–122 m (300–400 ft) from the energizer along the fence line. Construct a separate ground system. Connect a lightning arrester between the fence and the separate ground (see Figure 5–4. *Lightning protection showing arrester and ground*). Lightning arresters are available from farm supply dealers.

- Place the separate ground closer but not less than 30 m (100 ft) from the energizer. Install the lightning arrester. Install a lightning diverter coil or choke in the line anywhere between the arrester and the energizer (see Figure 5–5. *Lightning protection showing arrester, ground and a diverter coil*).

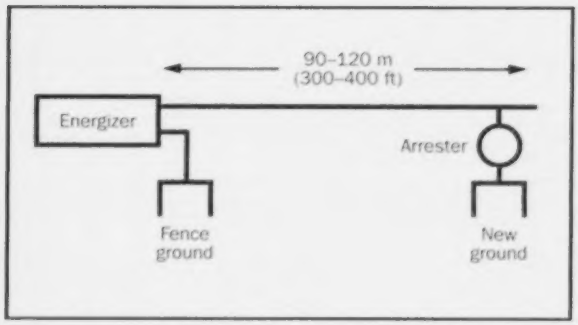


Figure 5–4. Lightning protection showing arrester and ground.

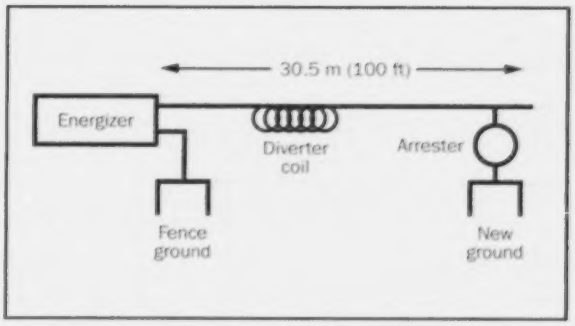


Figure 5–5. Lightning protection showing arrester, ground and a diverter coil.

PREDATOR CONTROL

Few fences are 100% predator proof. A 5-wire fence is the minimum for controlling dogs and wolves. Wires placed at 15 cm (6 in.), 30 cm (12 in.), 46 cm (18 in.), 66 cm (26 in.) and 91 cm (36 in.) from the soil are effective with alternating hot and ground wires. The bottom wire is a ground wire. A ground wire in contact with vegetation is not a drain on the charge. Using more wires adds to the cost but provides better control. A combination of electric and page wire along with guardian dogs and vigilant management has proven to be the most effective way to control predators, especially with small livestock.

FENCING MAINTENANCE

Maintenance adds years of life to a permanent fence. Loosen the wire tightener after the pasture season. This reduces stress on posts and insulators, and helps avoid cracks in the wire. Wire contracts in cold winter temperatures. Check the fence line in early spring for fallen trees, and for contact with old wire fencing, posts or trees. Check ground connections for dirt and rust build-up. Store energizers at temperatures above freezing when not in use.

6. Water Management on Pastures

WATER REQUIREMENTS

Water is an essential part of every animal's diet. An animal dies more quickly if deprived of water than if deprived of food. A newborn animal is made up of 75%–80% water, while 50% of a mature animal is water. Water is needed for digestion, absorbing nutrients, excreting waste and regulating body temperature. It is essential that pasture animals have an adequate source of clean water available at all times.

The amount of water an animal needs is affected by body size, milk production, feed intake, maturity of the plants being grazed and the weather. The average daily water requirements for livestock is listed in Table 6–1. *Livestock Water Requirements*.

Animals obtain some of their water requirements from their feed. Livestock grazing young, lush pastures do not need as much drinking water as animals grazing old, dry plants.

Hot temperatures, long hours of daylight and high relative humidity increase drinking water requirements, while rainfall decreases demand.

Most livestock drink very little at night and, given free access to water, drink between grazing cycles. Beef cattle drink four to six times a day, while high-producing dairy cows drink an average of 10 times a day. In dairy paddocks, it is important that the source of drinking water be close at hand. Dairy cattle cannot travel as far from water as beef cattle without suffering a decline in performance. The carrying capacity of individual paddocks where cattle were forced to travel greater than 250 m to water was 15%–20% less than paddocks where water was available within 250 m. Beef cows and calves should not travel more than 0.5 km to get water, or production is affected. Beef stockers should not have to go more than half that distance (0.25 km). Sheep and goats drink very little when on pasture and can travel more than 3.5 km for water without loss in production.

Table 6–1. Livestock Water Requirements

Animal	Litres/head/day	Gallons/head/day
Dairy	136	30
Beef cows	112	25
Beef stocker	67	15
Sheep	13	3
Horse	54	12

Providing good, clean water on dry footing helps prevent the spread of such diseases as foot rot. Muddy ponds, dugouts or stream banks provide a good medium for the spread of diseases.

Research by Agriculture and Agri-Food Canada at Stavely, Alberta, indicates that good-quality water pumped from a stream or well can increase calf and stocker gains by 23%, compared to drinking water from a pond.

BLUE-GREEN ALGAE POISONING

Animals drinking from standing water in the summer are potentially exposed to poisoning by blue-green algae.

Long periods of warm weather and a high content of organic matter in slow-moving or stagnant water can produce blue-green algae blooms. The algae produces a toxin that can cause chronic or acute poisoning.

Symptoms of poisoning develop very rapidly and resemble an allergic reaction. Animals are usually found dead at the water's edge or only a few metres away. In acute poisonings, the animal suffers from intestinal problems, internal bleeding and paralysis, leading to respiratory failure.

Small amounts of poison cause weakness and staggering. In some instances, apparent recovery from an attack is followed in a few days or weeks by evidence of photosensitization. There may be inflammation of the muzzle, the skin of the ear, the udder or other parts of the body. Jaundice is often seen, and constipation is a common symptom. Such cases usually recover under good care.

Table 6–2. Litres of Water Flow per Minute at Various Pipe Sizes and Distance

	Pipe Length									
Pipe Diameter	**30.5 m**	**61 m**	**107 m**	**152 m**	**229 m**	**305 m**	**457 m**	**610 m**	**1,067 m**	**1,600 m**
1.3 cm	15.0 L	11.4 L	—	7.6 L	—	—	3.8 L	—	—	—
1.9 cm	30.3 L	30.3 L	22.7 L	19.9 L	15.1 L	11.4 L	—	7.6 L	—	3.8 L
2.5 cm	49.2 L	49.2 L	37.9 L	30.3 L	26.5 L	22.7 L	18.9 L	15.1 L	11.4 L	7.6 L
3.2 cm	87.1 L	87.1 L	79.5 L	71.9 L	56.8 L	45.4 L	34.1 L	30.3 L	22.7 L	15.1 L
3.8 cm	113.6 L	113.6 L	113.6 L	98.4 L	83.3 L	71.9 L	56.8 L	45.4 L	34.1 L	26.5 L
5.1 cm	189.3 L	189.3 L	189.3 L	189.3 L	162.8 L	140.1 L	109.8 L	94.6 L	68.1 L	56.8 L

Table 6–3. Gallons of Water Flow per Minute at Various Pipe Sizes and Distances

	Pipe Length									
Pipe Diameter	**100 ft**	**200 ft**	**350 ft**	**500 ft**	**750 ft**	**1,000 ft**	**1,500 ft**	**2,000 ft**	**3,500 ft**	**1 mile**
½ in.	4 gal	3 gal	—	2 gal	—	—	1 gal	—	—	—
¾ in.	8 gal	8 gal	6 gal	5 gal	4 gal	3 gal	—	2 gal	—	1 gal
1 in.	13 gal	13 gal	10 gal	8 gal	7 gal	6 gal	5 gal	4 gal	3 gal	2 gal
1¼ in.	23 gal	23 gal	21 gal	19 gal	15 gal	12 gal	9 gal	8 gal	6 gal	4 gal
1½ in.	30 gal	30 gal	30 gal	26 gal	22 gal	19 gal	15 gal	12 gal	9 gal	7 gal
2 in.	50 gal	50 gal	50 gal	50 gal	43 gal	37 gal	29 gal	25 gal	18 gal	15 gal

Source: Kentucky Grazers Supply. *Watering Systems for Grazing Livestock.*

LIVESTOCK WATERING SYSTEM ALTERNATIVES

The problem of fecal bacterial contamination of some rural drainage systems can be partly attributed to livestock having contact with streams while watering. Livestock with access to water courses can tramp the bank and move sediment into the water, affecting fish habitat as well. Maintaining an adequate supply of clean water is an important part of herd management. Fence livestock from streams and provide an alternate water source. This benefits the health of your herd and the environment.

An alternative water supply may be necessary. If hydro is unavailable or water supply a problem, review the alternatives outlined below, paying particular attention to water source development and transfer mechanisms.

For pasture purposes, freezing of water systems is not considered.

Wells

Wells are the first choice for livestock water supply. Well water is clean, cool and the most desirable water supply. Water can be piped considerable distances to pastures using a water line that is laid on the surface along a fence line where the risk of tramping is minimal. Water lines made of 100-psi plastic hose with UV protection will last many years.

A major advantage of running water lines along the surface is that leaks are easily found and repaired. To winterize surface water lines, drain the water.

Using water lines makes setting up paddocks for rotational grazing and moving water through sites easier. The longer the water line, the larger diameter the pipe has to be. Tables 6–2 and 6–3 show volumes of water flow at various pipe lengths and diameters.

In some cases, it may be advantageous to drill a new well to service the pasture.

Discuss where to place a well with a competent well driller. Local well logs provide information on subsurface conditions and groundwater characteristics.

When suitable, locate the well in an accessible area convenient to pastures and near a storage reservoir, if needed. If possible, locate the well to take advantage of gravity flow to the point of use.

Springs

The purpose of spring development is to increase the flow of water, improve its accessibility and prevent contamination. **Remember to observe the proposed spring area during a dry period, to ensure the reliability of the source.**

Examine the aquifer material delivering water to the surface. Combine this with knowledge of local landform and drainage patterns, and you can make assumptions about the hydrogeological conditions influencing flow.

Increase flow by removing any material obstructing the up-welling flow at the spring outlet. Redirect surface runoff to avoid accumulating debris and contaminants. It may be possible to collect the flow from several outlets or along a seepage face. A graded ditch, exposing the length and depth of the aquifer, can collect water with gravel fill, tile or perforated pipe and drain to a central spring box. Use filter fabrics where fine-grained soils may cause clogging.

Ponds

Excavated off-spring ponds are the only type you can use for stock watering, since they will not affect or be affected by local stream water quality. Ponds may be fed by surface runoff, groundwater aquifers or both. Surface runoff is not recommended. Drainage tiles may be intercepted and directed into a pond if good water quality can be assured. Runoff water quality is largely dependent upon land management (cropping and tillage) in the drainage area.

Where a shallow aquifer or permanent high water table exists, a groundwater-fed pond may be practical.

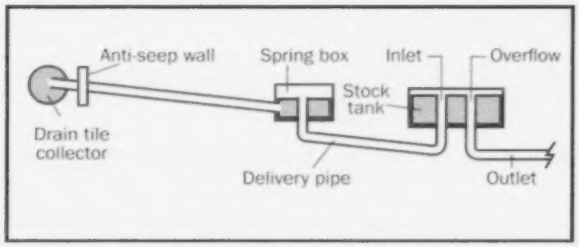


Figure 6–1. Gravity-powered watering system. A simple and dependable way of getting water to livestock.

Prior to excavation, conduct a soil investigation. Use a backhoe or auger. Put down test holes in a dry period of the year. Observe the depth of the water table. This will be the depth of the pond water. Check soil type for perviousness. Ponds must be located in impervious soils of high clay content to prevent seepage. Artificial linings of bentonite clay or synthetic materials may seal ponds in pervious sand or gravel soils but increase expense and complication. Nearby ponds are good sources of information on local conditions.

Aquifer- or groundwater-fed ponds also require test holes to evaluate the water-bearing material. The level of water in the test hole usually indicates the finished pond level for that period of the year. Pumping out the test hole and observing the recovery rate indicates the potential yield of the aquifer. As water tables vary with the season, make dry-period observations to avoid being misled by temporary conditions.

MOVING WATER WITH PUMP AND GRAVITY SYSTEMS

Gravity

The ability of water to flow from higher to lower elevations makes a gravity system the one to use whenever possible. With no moving parts or energy inputs, these systems can provide dependable, low-maintenance service (see Figure 6–1. *Gravity-powered watering system.*).

To allow for flow resistance in the pipe, a minimum delivery pipe diameter of 32 mm (1 ¼ in.) should be used where the grade is over 1%. For grades between 0.5% and 1.0%, a 38-mm (1 ½-in.) minimum size is recommended. Grades less than 0.2% are not recommended for gravity systems.

Lay the delivery pipe on a uniform grade to prevent airlocks from forming. Water tank volume should reflect livestock numbers and water demand. If necessary, add gravel to ensure the tank area is stable to withstand herd traffic. A float at the water tank or an overflow outlet would control these conditions. Put a shade canopy over the tank to control seasonal algae growth.

Solar Power

Photovoltaic (PV) or solar panels can be used to power pumping systems for a wide range of output requirements.

Solar systems can be very reliable and low in maintenance but require good design for practical service.

Two system designs can be used, depending upon the application. Both systems involve storing energy to compensate for variances in solar radiation intensity (see Figure 6–2. *Schematic of a solar-powered pumping system*).

Systems that use energy storage in the form of pumped water held in an elevated reservoir have the advantage of design simplicity. Solar panels supply power to the water pump through a maximum power point device to deliver water to the reservoir only during periods of bright sunlight. Water from the reservoir is gravity fed to the stock trough and controlled by a float valve.

Battery systems also store energy for use during periods of low sunlight intensity. Through a sequencing device, solar panels charge the batteries that power the water pump. Pump operation is controlled by an electric float switch to allow flow on demand to the stock trough.

Proper design of a solar system is critical to meet the specific needs of the user.

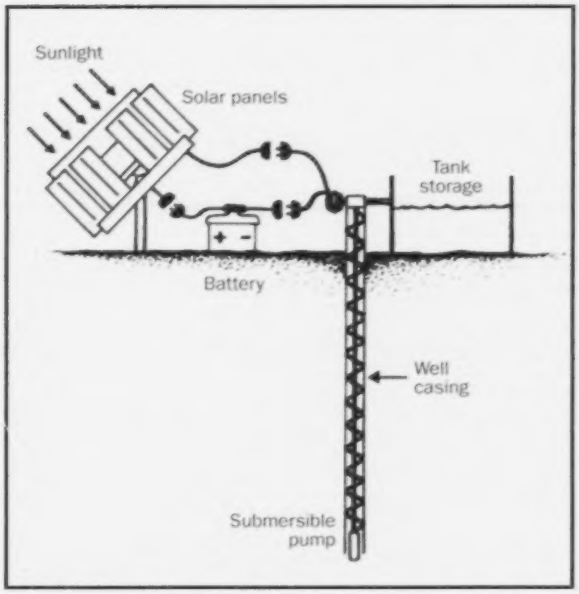


Figure 6–2. Schematic of a solar-powered pumping system.

Hydraulic Rams

Hydraulic ram pumps have been used since the 1700s. New designs with the same principles are being used today. Falling water is required to operate a hydraulic ram pump. If installed correctly, the pump moves water as high as 10 times the fall.

The weight of falling water drives a lesser amount to an elevation above the source of supply. The pump operates on the basis of the falling water opening and closing two valves with air pressure forcing the water to its destination. The volume of water a ram pumps depends on the size of the pump, the fall between the source of supply and the ram, the height to which the water is to be raised and the quantity of water available. Output ranges from 2,650–11,356 L (700–3,000 gal) per day, depending on these factors.

A small stream is an excellent source for watering livestock. Water needs to flow into the pump at 4–19 L (1–5 gal)/min. A fall of 0.6 m (2 ft) or more is sufficient to drive a ram capable of pumping water to a stock trough at considerable elevation and distance. As the pumping rate is constant but generally slow, a storage reservoir may be necessary to accommodate high-demand periods (see Figure 6–3. *A typical ram pump installation*).

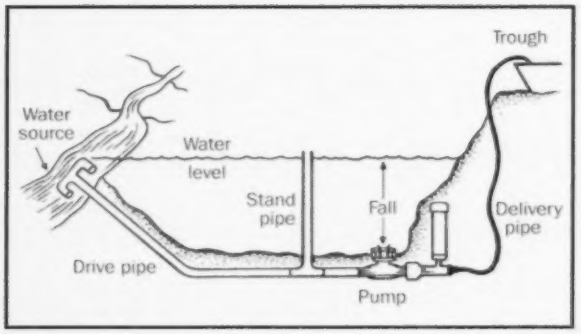


Figure 6–3. A typical ram pump installation. Ram pumps operate on the power of falling water.

Windmills

In the past, windmills have been a proven part of the farm enterprise and could find greater use for livestock water purposes today.

Though now a fairly expensive technology, currently manufactured windmills are reliable and need little maintenance, equal to their antique counterparts. Old windmills can be successfully rebuilt and may offer a practical alternative to the expense of new equipment.

Modern windmills will operate in a stream, pond or shallow well. The pump sits on the surface or in the water. An airline connects the pump to the windmill. Air pressure generated by the windmill activates the pump. Water is pumped when there is wind. The windmill can be located up to 91 m (300 ft) from the water source and at the best location to catch the wind. It can lift water up to 6 m (20 ft) and pump 19 L (5 gal)/min.

As wind is a variable energy source, use a storage reservoir to provide a supply for periods of low wind velocity. Locate the storage reservoir within 305 m (1,000 ft) of the water source.

Pasture (Nose) Pumps

Using a simple pumping mechanism to draw water to a bowl, the nose pump is a good alternative to in-stream watering. Installation is quick and easy — easy enough to use as a portable system for rotation pastures.

Figure 6–4. A nose pump operates on animal power.

Animals push a plunger with their nose to move water with a diaphragm pump into a bowl. The pump is a rubber diaphragm and two check valves. One push of the plunger brings water in on the forward stroke and again as it is released. The intake line incorporates a foot valve and strainer for reliable operation. The water source may be a nearby stream, pond or well of suitable quality.

A disadvantage of the nose pump is that stock must water individually, limiting practical use to about 25 animals per unit. Maximum lift from the water source is 8 m (25 ft). Where there is very little lift required, nose pumps can draw water from 61 m to 914 m (200 to 3,000 ft), depending on the pump size. Nose pumps are relatively low in cost, and installation expense is minimal. Animals must be trained to use them. Young calves may have difficulty at the beginning (see Figure 6–4. *A nose pump operates on animal power*).

Gasoline Engine–Powered Pumps

Portable gasoline-powered pumps that offer reliable service are available for water transfer where other systems are impractical. When used in combination with a large storage reservoir, it may be possible to limit time spent operating the pump. The major drawback with this system is the need for operator supervision during pumping and attention to the water volume in storage to assure a constant supply.

Water Troughs

With repeated use, the area around a water trough will become muddy. If troughs are permanently situated, provide an apron of gravel or other hard material around the trough so that the animals are standing on solid footing when at the trough. Gravel or concrete are the preferred materials for this apron. If using gravel, place filter cloth between the soil surface and the gravel to prevent mixing the gravel into the soil, resulting in a mud-gravel mix after repeated use.

If livestock need to travel a distance to the water, they will generally come as a group and a high-capacity trough will be required. With a rotational grazing system and water in each paddock, the livestock tend to drink individually or in small numbers, thus requiring a trough with a much smaller capacity.

7. Animal Health Problems

LIFE-THREATENING ILLNESSES

Grass Tetany

Grass tetany or hypomagnesemic tetany is a condition that occurs when an animal's daily diet does not provide enough magnesium to maintain a normal level of magnesium in the blood serum.

It is seen in adult animals sooner than young animals, and most often in cows and ewes shortly after giving birth. Cows milking heavily or sheep with twin lambs or triplets are more susceptible than lower-producing animals.

Symptoms

Symptoms of grass tetany are usually observed 5–10 days after animals are turned out to pasture. Lush spring grass pastures can be low in magnesium, with their high moisture content reducing dry matter intake, thereby reducing the intake of available magnesium to a critical level.

Typical symptoms are nervousness, tremors and twitching, staggering, convulsions and death. Death occurs quickly, within 6–10 hr after the onset of the first symptoms. An animal dead from grass tetany is usually found with the ground about it churned up, foam on its mouth and a pile of loose manure behind it. Blood serum magnesium levels can drop so quickly it is possible for tetany to occur on the first day out to pasture.

Chronic hypomagnesemia can also occur, with the plasma magnesium level dropping slowly over a relatively long time. The clinical symptoms of the disorder occur when the animal is under additional stress.

Prevention

The magnesium supply from pastures is affected by the botanical composition of the pasture, the stage of maturity of the plants, soil conditions and fertilizer treatments.

Legumes and herbaceous weeds tend to have a higher magnesium content than grasses. White clover is one of the best accumulators. Most of the commonly used grasses tend to have similar abilities to accumulate magnesium, with the exception of tall fescue and orchardgrass. Tall fescue is a better accumulator than most grasses, while orchardgrass is much worse. With both legumes and grasses there is a decline in magnesium content as the plants mature.

Wet, cold soils increase the chances of tetany occurring. Keep your animals off poorly drained pastures, particularly during periods of rainfall in spring and fall.

Fertilization affects the magnesium content in pastures in two ways:

- It changes the botanical composition of the pasture. Use of nitrogen on a legume-grass stand encourages grasses and can lead to a decline in the legume content.
- It directly affects (reduces) the magnesium concentration in the plants.

Nitrogen can increase the magnesium concentration in grasses when the soil magnesium level is not limited. However, if the soil magnesium concentration is low and there is a high potassium concentration, high nitrogen fertility may result in an excessive uptake of nitrogen and potassium and a reduced uptake of magnesium. Heavy potassium fertilization, alone, may also decrease magnesium uptake by plants growing in soil low in magnesium. Soil testing to determine the potassium and magnesium soil levels before fertilizing is an important step in preventing grass tetany.

Other options to prevent grass tetany include:

- feeding supplemental magnesium
- offering hay before turning the animals out onto lush grass pastures
- avoiding high rates of nitrogen by applying split applications
- applying potassium in the fall, not spring

If you suspect grass tetany, contact your veterinarian as soon possible.

Nitrate Poisoning

Nitrate is a normal plant metabolite. In a ruminant's digestive tract, nitrates are broken down into nitrites and ammonia. Toxicity may occur when the rate of production of nitrites exceeds the rate of conversion to ammonia. The formation of large amounts of nitrites is dangerous to the animal. Nitrite is absorbed into the bloodstream where it reacts with hemoglobin to form methemoglobin. This compound is incapable of releasing oxygen and, in lethal cases, the animal is killed by oxygen starvation.

Cattle are more susceptible to nitrate poisoning on pasture than sheep, goats or horses. Stressed animals are more vulnerable to nitrate poisoning.

Symptoms

The symptoms of acute poisoning are trembling, staggers, rapid breathing and dark-looking mucous membranes. Death can occur in as little as 3–4 hr. Non-fatal poisonings can cause poor growth, poor milk production and abortions. Vitamin A storage is also affected in cattle. Contact a veterinarian as soon as nitrate poisoning is suspected.

Causes

Normally, nitrate levels are low in the grasses and legumes commonly used in pastures. However, there can occasionally be enough nitrate accumulation to cause poisoning. Several factors influence nitrate accumulation by plants:

- Environmental conditions such as drought, uneven rainfall distribution, long periods of cloudy weather, high temperatures and frost increase nitrate accumulation by slowing down the plant's normal growth rate. If conditions improve and plants start actively growing, some of the accumulated nitrates will dissipate, and the danger of poisoning decreases.
- Some plants are naturally good accumulators of nitrates. These include species commonly used for annual pastures (small cereals, sorghum, sudangrass, forage rape and kale) and such weeds as lamb's quarters, thistles, pigweed and witchgrass.
- Nitrate levels are highest in vegetative plants, with nitrate accumulation peaking just before the plants start to bloom.
- There is a direct response in plant nitrate levels to increasing levels of nitrogen fertilizer. High nitrogen rates on grass pastures can cause some grass species (orchardgrass, tall fescue, meadow foxtail and reed canarygrass) to accumulate unsafe levels of nitrates. Nitrate accumulation is also greater with nitrate forms of fertilizer than with urea or ammonium sulphate.

Prevention

Due to the diverse factors influencing nitrate accumulation in plants, it is not possible to easily predict when nitrate poisoning may occur. To minimize the chance of poisoning, do not graze pastures containing a high percentage of plants that are good nitrate accumulators, or grass pastures treated with high amounts of nitrogen fertilizer, during or after periods of poor growth. Wait 10–14 days for the pasture to recover. A check on nitrate levels can be made by sending a sample (made up of pasture clippings) to a feed-testing laboratory.

Water may also be a source of nitrates to grazing animals. If nitrate poisoning is suspected, test both the plants and water to determine the source of the problem.

Bloat

Bloat results when an animal's rumen and reticulum become distended with gas. With pasture bloat, the gas is trapped in millions of bubbles, giving it a foamy appearance. The animal is unable to belch or burp up these small bubbles.

Symptoms

The visible result is that the animal's left flank starts to swell. The animal becomes uncomfortable, may kick at its belly, or get up and down more frequently than normal. Breathing becomes difficult, and the animal takes shallow, rapid breaths. The tongue may protrude, and there is some slobbering. Death can take place within 2–3 hr after the consumption of the bloating forage.

Causes
Bloating normally occurs on lush pastures with high alfalfa or clover content but can also happen when animals graze cereal crops, forage rape and young grass pastures with a high protein content. Alfalfa and ladino clover are considered more hazardous than white Dutch, red or alsike clovers.

Cattle appear to be more susceptible to bloat than other ruminants. In addition, some individual animals are more likely to bloat than others.

Prevention
The bloat hazard may be reduced in a number of ways:

- Plant pasture mixtures that do not have high percentages of bloat-causing legumes. In cattle pastures, limit the amount of bloat-causing legumes to 30%, while in pastures for other ruminants, do not exceed 50%.
- Use birdsfoot trefoil. It is the only commonly used legume that does not cause bloat.
- **Never turn hungry animals onto suspect pastures.** Feed hay to animals before they enter the pasture to prevent them from gorging on bloat-causing plants.
- Introduce animals to pastures that have bloat-causing legumes for only a short time. During the next few days, gradually lengthen the time the animals may remain in the field.
- Introduce animals to suspect pastures when the plants are dry. Heavy dew or moisture from rain increases the chances of bloating taking place.
- Wait until bloat-causing plants are flowering before grazing. Vegetative plants and legumes in prebud-to-bud stage are more likely to cause bloat.
- Use rotational grazing to maintain a steady rate of feed intake and to reduce selective grazing.
- Wait a few days after a killing frost before grazing suspect pastures. The risk of bloat occurring increases immediately after a killing frost.
- Use an anti-foaming agent such as Poloxalene when the potential for bloat is great.

Bloat can happen at any time during the grazing season. A close watch is needed at all times, as the bloat-producing potential of a pasture can change quickly.

Treatment
Bloated animals must be treated quickly. With the first signs of bloat, remove the animals from the pasture and consult a veterinarian. Keep the animals on their feet and dose the animals with an anti-foaming agent or surfactant such as mineral oil, raw linseed oil or liquid dishwashing detergent. In severe cases, when the animal has gone down and death is imminent, you must puncture the rumen and allow the gas to escape.

Prussic Acid Poisoning
Several plant species contain glycosides that can poison animals. Cyanogenic glycosides can be found in wild cherries, marsh arrow-grass, a few strains of New Zealand white clover and in plants in the sorghum family. The amount of cyanogenic glycosides found in these plants is influenced by plant genetics, stage of growth and environmental conditions.

Causes
When ingested, cyanogenic glycosides form prussic acid, which is highly toxic. The prussic acid interferes with the exchange of oxygen from the lungs to the body tissues.

Symptoms
The symptoms of acute poisoning are muscle tremors, difficult, rapid respiration and convulsions. Death can occur so quickly that the other symptoms are not observed.

Prevention
The highest levels of glycosides are usually found at early stages of plant growth. Do not graze sorghum-sudan hybrids until they reach a minimum height of 75 cm, and sudan grass, a minimum of 45 cm in height.

Environmental stress of any kind can increase the amount of cyanogenic glycoside to hazardous levels. After stresses such as drought, long periods of cloudy weather or frost, do not graze sorghum for at least a week. A check on cyanogenic glycoside levels can be done at a feed-testing laboratory.

Alsike Poisoning
Alsike clover can also cause a more serious form of poisoning in horses. Affected horses show nervous symptoms, loss of appetite, emaciation and jaundice. Paralysis and death can follow.

NON LIFE-THREATENING ILLNESSES

Infertility due to Phytoestrogens

Causes

Phytoestrogens are plant compounds found in legumes that can cause temporary to permanent infertility in animals. They can reduce not only the number of successful matings but also the number of multiple births and cause an increase in uterine prolapses. Phytoestrogen activity varies with the legume species, the plant strain and growing conditions.

In Ontario, red clover is the legume usually associated with causing temporary infertility problems. Red clover contains a class of fertility depressant compounds called isoflavones. The leaves of red clover are very high in isoflavone content, while the stems and petioles have lower levels. Isoflavones can cause infertility in sheep but appear to have little activity in cattle.

Prevention

If the feed contains more than 30% red clover, keep ewes off pasture or not fed silage for at least a month prior to flushing and mating. If more than 80% of the forage is red clover, problems with return to service and barrenness may occur. Varieties of red clover with reduced levels of isoflavones are not, at present, adapted for use in Ontario — **a predominantly red clover–based feed is not recommended for the breeding flock.**

Alfalfa, white clover and birdsfoot trefoil do not contain isoflavones. However, with severe insect or disease damage, these legumes can produce compounds called coumestans, which are also highly estrogenic. Planting legume varieties with good resistance to insects and diseases, proper grazing and fertility management, and growing legumes in mixtures with grasses helps remove coumestan fertility problems associated with sheep.

Molybdenum Poisoning

Causes

Molybdenum is an essential mineral for both plants and animals. However, accumulations of molybdenum in toxic levels can occur in plants growing on soils rich in molybdenum or low in copper. In certain parts of eastern Ontario, particularly in Dundas and Carleton counties, there are high quantities of molybdenum in the soil. Clovers are excellent accumulators of molybdenum, and this form of poisoning usually takes place on fields with a high clover content.

Cattle are more vulnerable than sheep to the adverse effects of high molybdenum levels.

Symptoms

The symptoms of poisoning in cattle are acute scouring, depressed milk production, weight loss, and rough, faded, black-to-red coats.

Sheep can also be affected and will show symptoms of copper deficiency, as molybdenum is an antagonist to copper.

Horses are tolerant to high molybdenum levels.

Photosensitivity

When eaten in large quantities, alfalfa, red clover, birdsfoot trefoil, alsike clover and perennial ryegrass can occasionally cause sensitization of an individual animal's unpigmented skin.

Symptoms

The affected skin area becomes swollen, reddened, itchy and, in advanced stages, the skin area hardens and peels away.

PROBLEMS CAUSED BY SPECIFIC FORAGES

Reed Canarygrass

The old varieties of reed canarygrass are known for being unpalatable and tough. Animals grazing the old varieties do not gain as well, produce as much milk or appear as thrifty as would be expected, based on the apparent feed quality. The cause is high levels of plant alkaloids. Alkaloids are bitter-tasting substances that are generally irritating to the gastrointestinal tract. New varieties of reed canarygrass have reduced levels of alkaloids. Feed quality, grass palatability and animal performance are excellent when these new varieties are pastured in the vegetative plant growth stage.

Tall Fescue

A fungal endophyte in tall fescue is thought to be responsible for causing three animal disorders: fescue foot, bovine fat necrosis and fescue toxicity. Their occurrence is determined by the percentage of infected tall fescue plants in the pasture, the length of time the animals spend grazing infected tall fescue, the weather and pasture fertility management.

Fescue Foot

Fescue foot can occur when animals graze tall fescue in cool weather. The symptoms include a rough hair coat, loss of weight, fever, quickened respiration rate, tenderness of the legs and, in advanced cases, loss of hooves, ears and the tail.

Bovine Fat Necrosis

Bovine fat necrosis is characterized by an accumulation of hard masses of fat along the alimentary tract. This condition results in digestive upsets and problems in giving birth. Pregnant horses grazing infected tall fescue do not prepare for foaling and may give birth to a dead foal. Remove pregnant mares from infected fields 30 days prior to the expected foaling date. Bovine fat necrosis is associated with fertilizing infected tall fescue pastures with high rates of nitrogen fertilizer or with broiler litter.

Fescue Toxicity

Fescue toxicity occurs during hot weather. The symptoms are poor gains, lowered conception rates, intolerance to heat, failure to shed the winter hair coat, fever, excessive salivation and nervousness.

Prevention

The only known means of spread of the endophyte is by infected seed. It is possible to prevent these associated animal disorders from occurring by using certified endophyte-free seed or by just using a small percentage of tall fescue in the pasture.

Perennial Ryegrass

Similar to fescue, perennial ryegrass also contains an endophytic fungus that causes a condition known as ryegrass staggers in sheep, cattle, horses, deer and llamas. Endophyte amounts will increase to toxic levels in warmer weather, then decrease to a safe concentration in cooler seasons. All above-ground parts of the plant may be infected with the fungus, but the highest concentrations are in the leaf sheaths, flower stalks and the seeds. As a result of this, during summer months when growth is slower and animals are grazing the plants closer to the ground, they will be consuming much larger amounts of the toxin. Ryegrass staggers develop over several days, beginning with tremors and incoordination, eventually causing the animal to collapse with flailing or stiffly extended limbs. When selecting ryegrass seed for pasture, make sure you purchase endophyte-free seed, not the endophyte-enhanced seed, which is intended for use as turfgrass.

Sorghum-Sudan Hybrids, Sudan Grass and Sorghums

Besides prussic acid poisoning (discussed above), these plants can cause urinary tract infections in horses. The symptoms are similar to colic but include bloody urine. The condition can be fatal, and it is recommended that horses not be allowed to graze these plants.

Brassicas

Brassicas are useful for extending the pasture season into the late fall. However, they do have problems. In addition to causing bloat and nitrate poisoning, they also cause forage rape poisoning, anemia, goitre, rape scald and rape blindness.

Forage Rape Poisoning

Forage rape poisoning can occur if animals graze stunted, purple-coloured rape plants. This type of plant is produced when rape growing in wet conditions or on soils deficient in phosphate, are frosted. Animals affected take shallow, rapid breaths and suffer from digestive disturbances. **Death may follow.** When the affected animals recover, they often remain unthrifty.

Anemia

Brassicas contain a hemolytic factor that may cause grazing animals to suffer from anemia. Cattle are more susceptible to this disorder than sheep. Anemia only develops when the livestock are grazing brassicas for at least 1 week. It usually takes 3 weeks to occur. In extreme cases, hemoglobin appears in the urine, giving it a red colour. The amount of the hemolytic factor in brassicas increases, as seeding dates are delayed in the summer with plant maturity.

Goitre

All brassica crops contain goitregenic substances. The goitregen affects the uptake of iodine by the thyroid gland, and goitre develops. Goitre can occur in all animals grazing brassicas but is more of a concern with sheep. Do not use brassica pastures during the mating season or for ewes late in their pregnancy. Lambs may be born dead or deformed.

Rape Scald

White-faced sheep grazing brassicas in August and September may suffer from "rape scald." Their light-coloured skin becomes susceptible to sunburning, and their heads may swell.

Forage rape can taint the flavour of milk and meat if it is the main source of feed.

Rape Blindness

Rape "blindness" is the sudden appearance of blindness in cattle and sheep grazing rape. Complete recovery of sight normally occurs a few weeks after the livestock have had a change of diet.

Limit the feeding of brassicas.

Appendices

Appendix A. Rotational Grazing Workbook

This workbook is designed so that you can apply the concepts discussed in this publication to your own cattle operation. Many farms will have a range of pasture/field capabilities. This work plan can be adapted for your situation. The following items should be considered.

1. Goals of Your Livestock Operation
2. Property Inventory
3. Preferred Rotational Grazing System
4. Forage Requirements and Paddock Size or Stocking Rates
   - Option A: Steps to determine your stocking rate if you are unable to vary your current number or size of paddocks
   - Option B: Steps to determine the number and size of paddocks needed based on your current stocking rate
5. Developing and Implementing the Plan
6. Recordkeeping and Monitoring

1. Goals of Your Livestock Operation

It is important to list and prioritize your goals for implementing rotational grazing, including any positive or negative implications.

Goal	Rank	Implications
e.g., increase stocking rate	1	Will need to put in more fencing to give pastures a chance to rest and increase forage production.
e.g., increase grazing days	2	Will need to increase forage availability during mid-summer.

2. Property Inventory

Sketch out your property, or use an air photo or Google Maps, and identify the soil types, forage type and quality, current fencing and water sources, as well as the locations of any sensitive areas (e.g., riparian or wetland areas, known wildlife nesting areas). Note the size of each pasture and any other descriptive pieces of information you know or observe.

Current Property Sketch — Soils, Water, Forage, Fencing and Sensitive Features

3. Preferred Rotational Grazing System

The type of grazing system you use is based upon your farm goals, personal preferences, landscape characteristics, ability to provide water and other similar considerations. More effort is required, the more paddocks you have. For example, if you want to move through eight paddocks in a twice-over grazing system, then you will have to shift the animals at least 16 times during the grazing system. If you wish to move them less often, you will have to decrease the number of paddocks and/or move to a single or once-over rotational grazing system. See Chapter 4 for a review of the different systems. The calculations below will also help you decide on the total number of paddocks if this number is not already fixed.

My preferred grazing system: _____

4. Forage Requirements and Paddock Size or Stocking Rates

To determine the number and sizes of paddocks needed to implement your chosen rotational grazing system, calculate the forage availability of your pastures. If the number of paddocks or their size is already set (or not adjustable), the variable that you will have to work with is stocking rate. Note that increased herd weights and increased number of grazing days can both play a role in determining the carrying capacity of the paddock. It is important to observe and adjust your numbers of cattle or days as conditions suggest.

IMPORTANT: Choose Section 4.1, Option A, or Section 4.2, Option B, below, to set up your grazing management plan, depending on your situation.

4.1. Option A: Steps to determine your stocking rate if you are unable to vary your current number or size of paddocks

4.1.1. Estimate the forage supply per paddock

The forage supply is the amount of forage dry matter (DM) available per hectare (acre) after the rest period. This value can be extremely variable between paddocks and years, and thus should be calculated for each paddock, or area of similar vegetation production. It can be estimated by clipping the forage when it is at peak biomass production from a square metre (square yard), air-drying it or drying it for 24 hr at a low oven temperature, weighing it, then extrapolating the square metre (square yard) results to the hectare (acre). However, this is very time consuming. Another method is to visually estimate the amount of available forage, then use a utilization factor of 75% for tame forage species or 50% for native forage species.

Step 1. Calculate forage supply per hectare or acre. Both metric and imperial options are provided below.

Formula:

Forage supply per hectare (kg forage DM/ha) available = estimated forage density (kg DM/ha) per area of similar vegetation x utilization factor

Forage supply per acre (lb forage DM/acre) available = estimated forage density (lb DM/acre) per area of similar vegetation x utilization factor

My Calculation:

kg DM/ha available = _____kg DM/ha estimated x 0.75 for tame forage or 0.50 for native species

lb DM/acre available = _____lb DM/acre estimated x 0.75 for tame forage or 0.50 for native species

Step 2. Calculate forage supply per paddock.

Formula:

Forage supply per paddock = forage supply per hectare x number of hectares per paddock

Forage supply per paddock = forage supply per acre x number of acres per paddock

My Calculation:

kg DM/paddock 1 = _____ kg DM/ha x _____number of hectares

lb DM/paddock 1 = _____ lb DM/acre x _____number of acres

My Calculation:

kg DM/paddock 2 = _____ kg DM/ha x _____number of hectares

lb DM/paddock 2 = _____ lb DM/acre x _____number of acres

4.1.2. Estimate the forage demand per animal

The forage demand can be calculated as the amount of forage DM required to feed one animal for one day. It is calculated based on the rule of thumb that grazing animals need to consume an amount of dry forage equal to about 2.5% of their body weight per day, and includes an additional 1% for trampling loss and buffer.

Formula:

Forage demand per animal (kg DM/day) = average weight/animal (kg) x 0.035

Forage demand per animal (lb DM/day) = average weight/animal (lb) x 0.035

My Calculation:

kg DM/day = _____kg x 0.035

lb DM/day = _____lb x 0.035

4.1.3. Calculate optimal stocking rate

When you have calculated the amount of forage you have available to graze in each paddock over the season, and the amount of forage needed per animal, you can calculate the optimal stocking rate. This involves three steps.

Step 1. Calculate the number of animal days per paddock.

Formula:

Number of animal days per paddock = forage supply per paddock ÷ forage demand per animal per day

My Calculation:

Number of animal days in paddock 1 = _____kg DM/overall paddock 1 ÷ _____ kg DM/day/animal

Number of animal days in paddock 1 = _____lb DM/overall paddock 1 ÷ _____ lb DM/day/animal

My Calculation:

Number of animal days in paddock 2 = _____kg DM/overall paddock 2 ÷ _____ kg DM/day/animal

Number of animal days in paddock 2 = _____lb DM/overall paddock 2 ÷ _____ lb DM/day/animal

Step 2. Calculate the total number of animal days overall.

Formula:

number of animal days overall = number of animal days in paddock 1 + number of days in paddock 2

My Calculation:

days overall = _____ days paddock 1 + _____ days paddock 2

Step 3. Calculate the total number of animals (herd size) the system can support that year.

Formula:

total number of animals in herd = total number animal days overall ÷ length of the grazing season in days

My Calculation:

animals in herd = _____ animal days ÷ _____ grazing days

4.1.4. Calculate the number of days available for grazing in each paddock

Once you know the total herd size, you can calculate how long the cattle can spend in each paddock before you need to shift them.

Formula:

Number days grazing per paddock = total number of animal days per paddock ÷ total number of animals in herd

My Calculation:

days grazing paddock 1 = _____animal days paddock 1 ÷ _____animals

My Calculation:

days grazing paddock 2 = _____animal days paddock 2 ÷ _____animals

4.2. Option B: Steps to determine the number and size of paddocks needed, based on your current stocking rate.

4.2.1. Estimate the forage supply per area

The forage supply is the amount of forage dry matter (DM) available per hectare (acre) after the rest period. This value can be extremely variable between paddocks and years, and thus should be calculated for each area of similar vegetation production. It can be estimated by clipping the forage when it is at peak biomass production from a square metre (square yard), air-drying it or drying it for 24 hr at a low oven temperature, weighing it and then extrapolating the square metre (square yard) results to the hectare (acre). However, this is very time consuming. Another method is to estimate the amount of available forage and then use a utilization factor of 75% for tame forage species or 50% for native forage species.

Formula:

kg forage DM/ha available = estimated density (kg DM/ha) per area of similar vegetation x utilization factor

lb forage DM/acre available = estimated density (lb DM/acre) per area of similar vegetation x utilization factor

My Calculation:

kg DM/hectare = _____kg DM/ha estimated x 0.75 for tame forage or 0.50 for native species

lb DM/acre = _____lb DM/acre estimated x 0.75 for tame forage or 0.50 for native species

4.2.2. Estimate the herd forage demand

The herd forage demand is the amount of forage dry matter (DM) required to feed the herd for one day. It is calculated based on the rule of thumb that grazing animals need to consume an amount of dry forage equal to about 2.5% of their body weight per day, and includes an additional 1% for trampling loss and buffer.

Formula:

Forage demand (kg DM/day) = average weight/head (kg) x 0.035 x number of head of cattle

Forage demand (lb DM/day) = average weight/head (lb) x 0.035 x number of head of cattle

My Calculation:

kg DM/day = _____kg x 0.035 x _____ head

lb DM/day = _____lb x 0.035 x _____ head

4.2.3. Decide on rest and grazing (residency) periods

The average rest period for a paddock of tame forage species is 30 days, but it can vary depending on the time of year and conditions. For example, 30 days rest after each grazing period, or 30 days rest in the spring after the first graze and 60 days rest later in the fall after the second graze.

The grazing (residency) period is the amount of time you want your cattle to remain in a particular paddock before moving them. It can vary depending on the desired management strategy and pasture conditions. For example, the grazing period could be 2 days with intensive rotational grazing systems, or 60 days in simple rotational grazing systems; it can be shorter when forage conditions are poor or longer when forage is plentiful. Your time and materials and labour costs must factor into this decision.

My Rest Period: _____ days

My Grazing (or Residency) Period: _____ days

4.2.4. Determine paddock size

The size of your paddock is dependent upon how long the cattle will be grazing there and the amount of forage available to them (i.e., forage demand).

Formula:

paddock size = herd forage demand x grazing period ÷ forage supply

My Calculation:

hectares = _____ kg/day x ____ grazing days ÷ _____ kg/ha/rotation

acres = _____ lb/day x ____ grazing days ÷ _____ lb/acre/rotation

4.2.5. Calculate number of paddocks

The minimum number of paddocks you need is based on the amount of time the forage is allowed to rest. An extra paddock is included as a buffer to ensure that all paddocks have a full rest period.

Formula:

number of paddocks = rest period/paddock in days ÷ grazing period/paddock in days + 1

My Calculation:

number of paddocks = _____ rest days ÷ ____ grazing days + 1

4.2.6. Estimate acreage required for rotational grazing

Once you have determined the optimum number of paddocks for your system, you can estimate the total amount of acreage required to support it. If the number of acres required is higher than you have access to for grazing then you may need to readjust your stocking rate or the number of days spent grazing per paddock.

Formula:

total acreage required for your rotational grazing plan = paddock size x number of paddocks

My Calculation:

hectares = _____ hectares/paddock x _____ paddocks

acres = _____ acres/paddock x _____ paddocks

5. Developing and Implementing the Plan

Re-draw or sketch your farm property to show the locations and shape of the new paddocks you wish to implement, the water sources, access points and other management features. Get advice from other experienced farmers or extension personnel to decide on the set-up and implementation. Then create a schedule based on the number of days the herd is to be in each paddock. Remember, if you are renting the land, be sure to get permission before making any modifications.

Details on the Proposed Management Plan

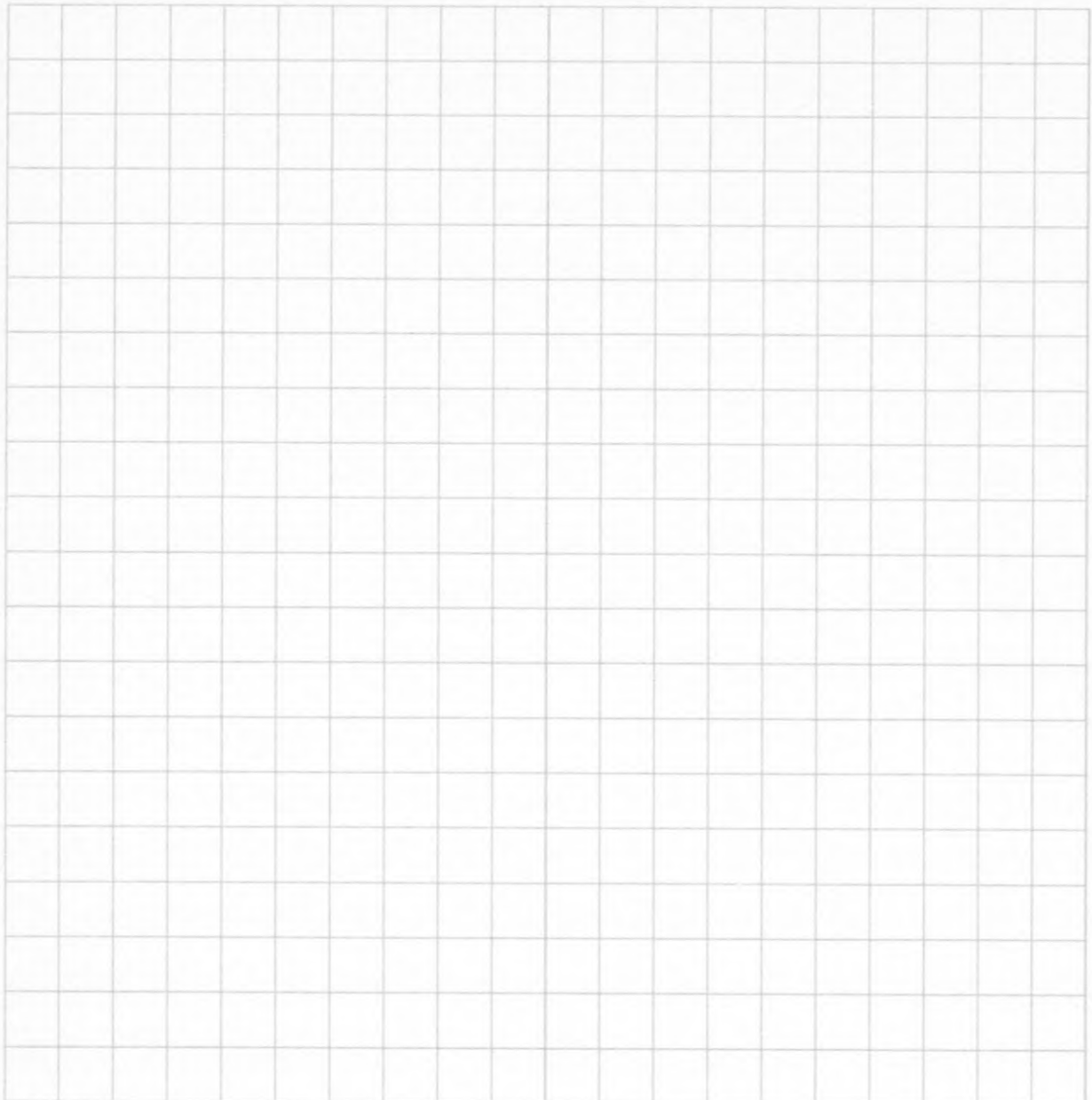
Management Plan Item	Paddock A	Paddock B	Paddock C	Paddock D
Acreage				
Forage species				
Pasture condition				
Paddock shape and fencing requirements				
Access or crossing points				
Stocking rates				
Scheduled grazing period start date*				
Scheduled grazing period end date*				
Grazing (residency) period				
Rest period				
Water source(s)				
Sensitive area management				

*Remember that the start and end dates must be flexible, based on conditions, and will likely vary year to year.

6. Recordkeeping and Monitoring

It is important to keep track of information such as forage growth rates, the amount of forage that remains after grazing season, the number of cattle grazed each year, their pre- and post-grazing weights, their health, the length of the grazing period, the size of each paddock, the density and species of weeds and techniques used to manage them, the amount of exposed soil and similar factors. This allows you to compare year to year and can indicate whether your pastures are overgrazed or undergrazed, whether stocking rates should be increased, decreased or maintained, and whether the forage is improving or not. This information can be collected in a table similar to the table above, and included with your plan. Review and update your rotational grazing plan over time accordingly.

Updated Sketch of Property



Appendix B. The Metric System

Metric units

Linear measures (length)

10 millimetres (mm) = 1 centimetre (cm)
100 centimetres (cm) = 1 metre (m)
1,000 metres = 1 kilometre (km)

Square measures (area)

100 m × 100 m = 10,000 m^2 = 1 hectare (ha)
100 ha = 1 square kilometre (km^2)

Cubic measures (volume)

Dry measure

1,000 cubic millimetres (mm^3) = 1 cubic centimetre (cm^3)
1,000,000 cm^3 = 1 cubic metre (m^3)

Liquid measure

1,000 millilitres (mL) = 1 litre (L)
100 L = 1 hectolitre (hL)

Weight-volume equivalents (for water)

(1.00 kg) 1,000 grams = 1 litre (1.00 L)
(0.50 kg) 500 g = 500 mL (0.50 L)
(0.10 kg) 100 g = 100 mL (0.10 L)
(0.01 kg) 10 g = 10 mL (0.01 L)
(0.001 kg) 1 g = 1 mL (0.001 L)

Weight measures

1,000 milligrams (mg) = 1 gram (g)
1,000 g = 1 kilogram (kg)
1,000 kg = 1 tonne (t)
1 mg/kg = 1 part per million (ppm)

Dry–liquid equivalents

1 cm^3 = 1 mL
1 m^3 = 1,000 L

Dry weight conversions (approximate)

Metric	Imperial
grams or kilograms/hectare	ounces or pounds/acre
100 g/ha	1½ oz/acre
200 g/ha	3 oz/acre
300 g/ha	4¼ oz/acre
500 g/ha	7 oz/acre
700 g/ha	10 oz/acre
1.10 kg/ha	1 lb/acre
1.50 kg/ha	1¼ lb/acre
2.00 kg/ha	1¾ lb/acre
2.50 kg/ha	2¼ lb/acre
3.25 kg/ha	3 lb/acre
4.00 kg/ha	3½ lb/acre
5.00 kg/ha	4½ lb/acre
6.00 kg/ha	5¼ lb/acre
7.50 kg/ha	6¾ lb/acre
9.00 kg/ha	8 lb/acre
11.00 kg/ha	10 lb/acre
13.00 kg/ha	11½ lb/acre
15.00 kg/ha	13½ lb/acre

Liquid equivalents (approximate)

50 L/ha = 4.45 gal/acre (5.35 US gal/acre)
100 L/ha = 8.90 gal/acre (10.70 US gal/acre)
150 L/ha = 13.35 gal/acre (16.05 US gal/acre)
200 L/ha = 17.80 gal/acre (21.40 US gal/acre)
250 L/ha = 22.25 gal/acre (26.75 US gal/acre)
300 L/ha = 26.70 gal/acre (32.10 US gal/acre)

Application rate conversions (approximate)

Metric to Imperial or U.S.

litres per hectare × 0.09 = Imp. gallons per acre
litres per hectare × 0.11 = U.S. gallons per acre
litres per hectare × 0.36 = Imp. quarts per acre
litres per hectare × 0.43 = U.S. quarts per acre
litres per hectare × 0.71 = Imp. pints per acre
litres per hectare × 0.86 = U.S. pints per acre
millilitres per hectare × 0.014 = U.S. fluid ounces per acre
grams per hectare × 0.014 = ounces per acre
kilograms per hectare × 0.89 = pounds per acre
tonnes per hectare × 0.45 = tons per acre

Imperial or U.S. to metric

Imp. gallons per acre × 11.23 = litres per hectare (L/ha)
U.S. gallons per acre × 9.35 = litres per hectare (L/ha)
Imp. quarts per acre × 2.8 = litres per hectare (L/ha)
U.S. quarts per acre × 2.34 = litres per hectare (L/ha)
Imp. pints per acre × 1.4 = litres per hectare (L/ha)
U.S. pints per acre × 1.17 = litres per hectare (L/ha)
Imp. fluid ounces per acre × 70 = millilitres per hectare (mL/ha)
U.S. fluid ounces per acre × 73 = millilitres per hectare (mL/ha)
tons per acre × 2.24 = tonnes per hectare (t/ha)
pounds per acre × 1.12 = kilograms per hectare (kg/ha)
pounds per acre × 0.45 = kilograms per acre (kg/acre)
ounces per acre × 70 = grams per hectare (g/ha)

Metric conversions

5 mL = 1 tsp
15 mL = 1 tbsp
28.5 mL = 1 imp. fl. oz.

Conversion tables – metric to imperial (approximate)

Length
1 millimetre (mm) = 0.04 inches
1 centimetre (cm) = 0.40 inches
1 metre (m) = 39.40 inches
1 metre (m) = 3.28 feet
1 metre (m) = 1.09 yards
1 kilometre (km) = 0.62 miles
Area
1 square centimetre (cm^2) = 0.16 square inches
1 square metre (m^2) = 10.77 square feet
1 square metre (m^2) = 1.20 square yards
1 square kilometre (km^2) = 0.39 square miles
1 hectare (ha) = 107,636 square feet
1 hectare (ha) = 2.5 acres
Volume (dry)
1 cubic centimetre (cm^3) = 0.061 cubic inches
1 cubic metre (m^3) = 1.31 cubic yards
1 cubic metre (m^3) = 35.31 cubic feet
1,000 cubic metres (m^3) = 0.81 acre-feet
1 hectolitre (hL) = 2.8 bushels
Volume (liquid)
1 millilitre (mL) = 0.035 fluid ounces (Imp.)
1 litre (L) = 1.76 pints (Imp.)
1 litre (L) = 0.88 quarts (Imp.)
1 litre (L) = 0.22 gallons (Imp.)
1 litre (L) = 0.26 gallons (U.S.)
Weight
1 gram (g) = 0.035 ounces
1 kilogram (kg) = 2.21 pounds
1 tonne (t) = 1.10 short tons
1 tonne (t) = 2,205 pounds
Pressure
1 kilopascal (kPa) = 0.15 pounds/$in.^2$
Speed
1 metre per second = 3.28 feet per second
1 metre per second = 2.24 miles per hour
1 kilometre per hour = 0.62 miles per hour
Temperature
°F = (°C × ⅘) + 32

Conversion tables – Imperial to metric (approximate)

Length
1 inch = 2.54 cm
1 foot = 0.30 m
1 yard = 0.91 m
1 mile = 1.61 km
Area
1 square foot = 0.09 m^2
1 square yard = 0.84 m^2
1 acre = 0.40 ha
Volume (dry)
1 cubic yard = 0.76 m^3
1 bushel = 36.37 L
Volume (liquid)
1 fluid ounce (Imp.) = 28.41 mL
1 pint (Imp.) = 0.57 L
1 gallon (Imp.) = 4.55 L
1 gallon (U.S.) = 3.79 L
Weight
1 ounce = 28.35 g
1 pound = 453.6 g
1 ton = 0.91 tonne
Pressure
1 pound per square inch = 6.90 kPa
Temperature
°C = (°F – 32) × ⅝

Abbreviations

%	= per cent
ai	= active ingredient
AP	= agricultural powder
cm	= centimetre
cm^2	= square centimetre
CS	= capsule suspension
DF	= dry flowable
DG	= dispersible granular
DP	= dispersible powder
E	= emulsifiable
EC	= electrical conductivity
e.g.	= for example
F	= flowable
g	= gram
Gr	= granules, granular
ha	= hectare
kg	= kilogram
km/h	= kilometres per hour
kPa	= kilopascal
L	= litre
m	= metre
m^2	= square metre
mL	= millilitre
mm	= millimetre
m/s	= metres per second
SC	= sprayable concentrate
SP	= soluble powder
t	= tonne
W	= wettable (powder)
WDG	= water dispersible granular
WG	= wettable granule
WP	= wettable powder

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